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Great Lakes Basin Commission, Ann Arbor, MI

Prepared for

International Joint Commission-United States and Canada, Windsor (Ontario)

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This report summarizes data contained in five lake-specific volumes which describe and quantify, as appropriate, the U.S. Great Lakes Basin's geology, soils, minerals, climate, surface and ground water, vegetation, wildlife, and economic and demographic characteristics. It provides an overview of available information on waste disposal operations, lakeshore and riverbank erosion, high-density non-sewered residential areas, and recreational land uses as well as materials application of agricultural chemicals, fertilizers, lime, animal wastes, and salts on highways. Future trends and projections are shown.

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S POLLUTION
E ACTIVITIES

INTERNATIONAL
JOINT
COMMISSION

INVENTORY OF LAND USE AND LAND USE PRACTICES
VOLUME I - GREAT LAKES BASIN

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INVENTORY OF LAND USE AND LAND USE PRACTICES IN THE UNITED STATES GREAT LAKES BASIN

REPORT OF THE INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

VOLUME I
GREAT LAKES BASIN

MARCH 1976

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INVENTORY OF LAND USE AND LAND USE PRACTICES IN THE UNITED STATES GREAT LAKES BASIN with Emphasis on Certain Trends and Projections to 1980 and Where Appropriate, to 2020

prepared by the office of the
GREAT LAKES BASIN COMMISSION
Ann Arbor, Michigan

To be used as portion of the U.S. Task B Report on GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES BY the International Joint Commission - prepared in partial fulfillment of U.S. Environmental Protection Agency Contract No. 68-01-1598

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The sections on physical fabric, specialized land uses, materials usage, and trends in all six volumes of this study (a summary and five Lake basin volumes) were prepared by Suzanne Braley, Louis Meyer, and Robert Reed, of the Great Lakes Basin Commission staff, Ann Arbor, Michigan, with general coordination by Eugene Jarecki.

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(1) Soils--Alan Irvine, Jackson, Michigan (funded by ESDA-SCS)
(2) Materials Usage--John Doneth, Michigan State University, East Lansing, Michigan (funded by USDA-SCS)
(3) Revised OBERS Series E Economic and Demographic Projections--Waldon Miller and John Putman, Economic Research Service USDA, East Lansing, Michigan (funded by USEPA under subcontract with GLBC)
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TABLE OF CONTENTS

	Page No.
LIST OF TABLES	vii
LIST OF FIGURES	x
PREFACE	xi
INTRODUCTION AND SUMMARY	1
Introduction	1
Detailed Study Plan, February 1974	1
Purpose	2
Scope of Study	2
Physical Fabric	2
Major Land Uses (LARS)	2
Specialized Land Uses	2
Materials Usage	3
Future Trends	3
General Summary	3
Physical Fabric	5
Land Uses (LARS)	5
Specialized Land Uses	5
Materials Usage	8
Trends	9
PHYSICAL FABRIC	10
The Great Lakes Basin	10
Land Resources	12
Geology, Physiography, and Topography	12

Page No.

Soils 18
Minerals 19

Climate 19

Surface and Ground Water 24

Ground Water 24
Surface Water 28

Vegetation Zones and Wildlife Habitat 31

Demographic and Economic Characteristics 33

Population 33
Resource Use and Development 36

References 38

MAJOR LAND USES 39

Introduction 39

Approach 40
Results 40

Land Use Inventory Procedures 41

Processing and Analysis 42
Classification Variations 53

Results 54

Summary and Conclusions 57

Land Use Inventory by Remote Sensing 57
Advances in Technology 59
Future Information Systems 59
Conclusions 59

References 61

SPECIALIZED LAND USES 63

Disposal Operations 63

Liquid Waste Disposal 63
Solid Waste Disposal 64
Dredge Spoil Disposal 66
Deepwell Disposal 68

Page No.

Erosion 68

- Lakeshore Erosion 68
- Riverbank Erosion 72

Intensive Livestock Operations 73

High Density, Nonsewered Residential Areas 74

Recreational Land Use 75

References 77

MATERIALS USAGE 79

Inventory of Present Materials Usage 79

- Agricultural Chemicals 86
- Animal Wastes 86
- Commercial Fertilizers 86
- Lime 87
- Salts 87

Materials Usage Trends 87

- Agricultural Chemicals 87
- Animal Wastes 88
- Commercial Fertilizers 88
- Lime 88
- Salts 89

Methodology 89

- General 89
- Definition of Terms 89
- Agricultural Chemicals 91
  - Nationwide Chemical Usage 91
  - Great Lakes Basin Chemical Usage 92
  - Chemical Usage for Vegetables 93
  - Chemical Usage for Fruits 97
- Animal Wastes 99
- Commercial Fertilizers 99
- Lime 100
- Salts 100

References 102

Page No.

FUTURE TRENDS 105

Summary and Conclusions 105

Demographic, Economic, and Land Use Characteristics 106

Population 106
Economics 107
Agricultural Production 107
Livestock 107
Land Use 110

Alternative Futures 111

Demographic Trends 112
Economic Trends 115
Agricultural Trends 118
Livestock Trends 122
Land Use Trends 123

Specialized Land Uses 124

Disposal Operations 124

Liquid Waste Disposal 124
Solid Waste Disposal 126
Dredge Spoil and Artificial Fill 127
Deepwell Disposal 128

Erosion 129

Lakeshore Erosion 129
Riverbank Erosion 130

Intensive Livestock Operations 130
High-Density, Nonsewered Residential Areas 131
Recreational Lands 133

Materials Usage 133

Agricultural Chemicals 133
Animal Wastes 139
Commercial Fertilizers 139
Lime 139
Salts 139

Methodology 140

Economic and Demographic Activities 141
Specialized Land Use 142

Page No.

Disposal Operations 142
Erosion 143
Intensive Livestock Operations 143
High-Density, Nonsewered Residential Areas 143
Recreational Lands 144

Materials Usage 144

Agricultural Chemicals 144
Animal Wastes 145
Commercial Fertilizers 145
Lime 145
Salts 145

References 146

LIST OF TABLES

Table Number		Page Number
1	Counties in the Great Lakes Region	6
2	Great Lakes Area Measurement	7
3	Great Lakes Surface Area, U.S. and Canada	11
4	Average Levels of the Great Lakes, IGLD (1955)	30
5	Population Distribution, Great Lakes Region	34
6	Employment by Selected Industries, 1950-1970	36
7	Land Use Categories Classified	40
8	Counties Included in Pilot Study	46
9	Class Definitions	50
10	Proposed Land Use Classification Categories	52
11	Final Land Use Classification Categories	53
12	Color Code for County Maps	55
13	Land Use Area: Great Lakes Region	58
14	Liquid Waste Disposal by Sites	64
15	Solid Waste Disposal Sites	65
16	Average Annual Volume of Dredge Spoil Disposal	66
17	Deepwell Disposal Sites	67
18	Great Lakes Shore Type	69
19	Great Lakes Shoreline Erosion	71
20	Michigan High-Risk Shoreline Erosion Mileage	72
21	Total Length of Streambank Erosion	73
22	Number of Intensive Livestock Operations	74
23	High-Density, Nonsewered Residential Areas	75
24	Summary of Recreational Areas and Activities	76
25	Chemicals Used by Class and by Harvested Cropland Acre	80
26	Manure Tonnage by PSA and Kind of Livestock	81
27	Intensity of Manure and Primary Manure Nutrients per Harvested Acre	82
28	Commercial Fertilizers Use and Nutrient Intensity	83
29	Lime and Road De-Icers per Harvested Acre and Index of Use	84
30	Great Lakes Basin Materials Usage Inventory	85
31	Quantities of Selected Pesticides Used by U.S. Farmers, 1966 and 1971	91
32	Cropland Chemical Treatment: Intensity by Crop and Chemical Type	94
33	Wisconsin Vegetable Acres for 1972 and Chemicals Applied	98

Table Number		Page Number
34	Pounds of Chemicals Applied per Acre Bearing Fruit	99
35	Animal Manure Multipliers	100
36	Population Levels, 1950-71	107
37	Population, Employment, Personal Income, and Earnings by Industry, 1970	108
38	Agricultural Production, Great Lakes Basin Current Normal Average (1958-1972)	109
39	Livestock Production: 1972	110
40	Present Land Use	111
41	Agricultural Acreage Under Cultivation by Categories	112
42	Agricultural Land Use, Great Lakes Study Area Current Normal Average	113
43	Projected Population Growth: Great Lakes Basin	115
44	Population, Employment, Personal Income, and Earnings by Industry: 1970, 1980, 2000, 2020 (Series E)	116
45	Population, Employment, Personal Income, and Earnings by Industry: 1970, 1980, 2000, and 2020, Series C, Great Lakes Basin	117
46	Crop Production, Projections for 1980, 2000, and 2020, Series E, Great Lakes Basin	121
47	Crop Production, Projections for 1980, 2000, 2020, Series C, Great Lakes Basin	122
48	Projected Livestock Production, 1980, 2000, 2020, Series E, Great Lakes Basin	123
49	Projected Livestock Production, 1980, 2000, 2020, Series C, Great Lakes Basin	124
50	Land Use Projections, 1980, 2000, 2020, Series C and Series E, Great Lakes Basin	125
51	Projected Extractive Mineral Land Requirements, Great Lakes Basin	126
52	Projected Liquid Waste Disposal Requirements: Great Lakes Basin	127
53	Projected Solid Waste Disposal Requirements: Great Lakes Basin	128
54	Dredge Spoil: Projected Amount of Annual Maintenance	129
55	Trends in Erosion	130
56	Projected Number of Livestock Held in Intensive Livestock Operations	131
57	Number of Households in High-density, Non-sewered Residential Areas	132
58	Trends in Recreational Activity Occasions Annually	135
59	Trends in Recreational Land Development by Activity	137
60	Trends in Materials Usage: Agriculture	138
61	Trends in Road De-icing Salt Usage	140

LIST OF FIGURES

Figure Number		Page Number
1	Great Lakes Basin	4
2	Percentage of Total Region Area in Each State	12
3	Great Lakes Region Planning Subareas	13
4	Glacial Geology of the Great Lakes Basin	15
5	Bedrock Geology of the Great Lakes Basin	16
6	Physiography of the Great Lakes Region	17
7	Great Lakes Region: Distribution of Bedrock Geology and Principal Mineral Production	20
8	Mean Maximum Temperatures - Great Lakes Basin	22
9	Mean Annual Precipitation and Its Coefficient of Variation	23
10	Climate Characteristics Selected Cities	25
11	Estimated Ground Water Yield in the Great Lakes Basin	26
12	Profile of the Great Lakes System	29
13	Major Forest Types	32
14	Population per Square Mile for Great Lakes Region Counties	35
15	Location of Quarter Sections, Green Lake County Wisconsin	47
16	Sample Area Report Form	48
17	Sample Area Report Form Instructions	49
18	Great Lakes Region	56
19	Distribution of Great Lakes Shore Types	70
20	Population Levels: 1950 to 2020	114
21	Earnings by Sector: 1970 to 2020	119
22	Total Earnings: 1970 to 2020	120

PREFACE

As its title suggests, this volume presents an Inventory of Land Use and Land Use Practices in the U.S. Great Lakes Basin, with emphasis on certain trends and projections to 1980 (and to 2020 where appropriate). The report, prepared by the Great Lakes Basin Commission staff, integrates several studies by contractors and subcontractors. These studies were part of the U.S. Task B effort for the Great Lakes Pollution from Land Use Activities Reference Group, International Joint Commission. The Task A report, Management Programs, Research and Effects of Present Land Use Activities on Water Quality of the Great Lakes, dated November 1974, preceded the Task B study.

The Task B report for the United States part of the Great Lakes Basin is contained in six volumes:

Volume I --Great Lakes Basin
Volume II --Lake Superior basin
Volume III--Lake Michigan basin
Volume IV --Lake Huron basin
Volume V --Lake Erie basin
Volume VI --Lake Ontario basin

Knowledge of present and future land use and land use practices are important as background to evaluating and controlling nonpoint sources of water pollution. This report describes and quantifies, as appropriate, the Great Lakes Basin's geology, soils, minerals, climate, surface and ground water, vegetation, wildlife, and economic and demographic characteristics. It inventories available information on waste disposal operations, lakeshore and riverbank erosion, high-density nonsewered residential areas, and recreational land uses as well as materials application of agricultural chemicals, fertilizers, lime, animal wastes, and salts on highways. Finally, future trends and projections are shown for the above categories.

This Great Lakes Basin Summary and each of the five Lake basin volumes have been reviewed by Joint Task Group B, whose comments were considered before approval for final report development and submittal to the U.S. Environmental Protection Agency for meeting contractual terms. This study forms a U.S. contribution to the U.S. Task B effort of the study on Great Lakes Pollution from Land Use Activities.

The study discussed in this report was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-U.S. Great Lakes Water Quality Agreement of 1972. Funding was provided through U.S. Environmental Protection Agency. Findings and conclusions are those of the author(s) and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

INTRODUCTION AND SUMMARY

INTRODUCTION

The Great Lakes Water Quality Agreement, with Annexes and Texts and Terms of Reference Between the United States of America and Canada, signed at Ottawa on April 15, 1972, included a reference to study pollution in the Great Lakes System from agricultural, forestry, and other land use activities. The reference asked that the study assess whether the boundary waters of the Great Lakes System were being polluted by land drainage and, if so, what remedial measures would provide improvements in controlling pollutants from land usage. The need for better definition of the impact of land use activities, practices, and programs on water quality in the Great Lakes area had become increasingly magnified. Through the Agreement, both the United States and Canadian governments requested the International Joint Commission to investigate land use activity impacts upon the Great Lakes. Accordingly, the International Reference Group on Great Lakes Pollution from Land Use Activities was established in December, 1972, and produced a detailed study plan (February, 1974 and updated with the detailed study plan supplement - August, 1976) outlining an intensive study scheduled for completion in 1978.

The final report will consist of study conclusions and recommendations by PLUARG to the International Joint Commission.

Detailed Study Plan, February, 1974

The study plan emphasizes four main tasks:

Task A: assessment of problems, management programs and research, and the attempt to set priorities in relation to the best information now available on the effects of land use activities on water quality in boundary waters of the Great Lakes

Task B: inventory of land use and land use practices, with emphasis on certain trends and projections to 1980 and, if possible, to 2020

Task C: intensive studies of a small number of representative watersheds, selected and conducted to permit some extrapolation of data to the entire Great Lakes Basin and to relate contamination of water quality, which may be found at river mouths on the Great Lakes, to specific land uses and practices

Task D: diagnosis of the degree of impairment of water quality in the Great Lakes, including assessment of concentrations of contaminants of concern in sediments, fish, and other aquatic resources.

PURPOSE

Background information on characteristic Basin properties such as land use and related materials usage, physical fabric, climate, population, and water quality relationships and providing a foundation for assessment of trends in land use patterns and practices. Towards these ends the Reference Group felt that an inventory of land use and land use practices with emphasis on certain trends and projections to 1980 and 2020 is essential to assist in developing the planning and management of land to minimize runoff of pollutants in drainage water.

The objectives of the Task B effort are directed towards the following activities:

(1) to provide a general land use inventory of the Great Lakes Basin

(2) to provide specific information concerning the nature and location of defined specialized land use categories in the Great Lakes Basin

(3) to provide information on the physical fabric of the Great Lakes Basin including soils and their capability, hydrology, geomorphology, climate, mineral and gas resources, and broad vegetation zones

(4) to provide an inventory of various materials applied to land which may influence the quality of drainage waters

(5) to provide a consistent and comprehensive set of forecasts for 1980 and 2020 relating to land uses and land use activities based upon socioeconomic, technological, and political development.

SCOPE OF STUDY

In order to meet the Task B objectives for the U.S. portion of the Great Lakes, members of Task Group B agreed on studies in five categories: physical fabric, major land uses, specialized land uses, materials usage, and future trends.

Physical Fabric

The objective of this activity is to provide background information and data on the physical fabric of the individual Great Lakes Basins, focusing on the land drainage/water quality relationships, and to provide a detailed description of the basin in terms of climate, population, and socioeconomic conditions.

Major Land Uses

The objective of this activity is to gather information about the generalized land use patterns in the Great Lakes Basin. This information is derived from computer analysis of multispectral scanner (MSS) data from the LANDSAT - 1 Program (formerly known as the Earth Resources Technology Satellite).

Specialized Land Uses

The objective of this activity is to provide specific information concerning the nature and location of specific land use categories in the Great Lakes Basin. The following specialized land uses comprise this section:

(1) disposal operations, liquid waste, solid waste, dredge spoil and artificial fills, and deepwell disposal
(2) erosion, lakeshore and riverbank
(3) intensive livestock operations
(4) high-density, nonsewered areas
(5) recreational lands.

Materials Usage

This activity provides an inventory of production and/or usage within the Great Lakes Basin of certain materials applied to lands with a potential for reaching the Great Lakes through land drainage. The materials to be inventoried include pesticides, agricultural manures, chemical fertilizers, agricultural liming materials, and road salts.

Future Trends

The objective is to identify and assess future trends in major land uses, specialized land uses, materials usage, and related information which may affect the drainage of pollutants into the Great Lakes for the target years 1980, 2000, and 2020.

To make the information more usable, the U.S. Task B Inventory has been organized into six volumes--this volume summarizing information for the Great Lakes Basin as a whole, and five other volumes addressing each of the five individual Lake basins. Figure 1 indicates the area of study for this volume. The information in the other volumes has been subdivided under individual planning subareas representing the major drainage basins tributary to each Lake. Basic information for each planning subarea is presented on a county basis.

GENERAL SUMMARY

The Task B effort is aimed at providing an inventory of various categories affecting land drainage or pollutional materials to the Great Lakes. In generating data necessary to complete the inventory, a variety of sources were utilized, including state agencies, recognized experts in the field, and published reports and documents, in addition to information contained in the Task A Reports. Some background information has been compiled as supporting data for this inventory. This material is available for review at the Great Lakes Basin Commission in Ann Arbor, Michigan.

Because most of the data collected reflects conditions between 1970 and 1972, it may not reflect exactly the current situation. However, it seems reasonable to assume that no major changes have occurred in the last four years to significantly alter the general picture this information attempts to portray. Ideally a continuous updating of this information would be of significant utility to researchers, planners, and those involved with managing the water resources of the Great Lakes.

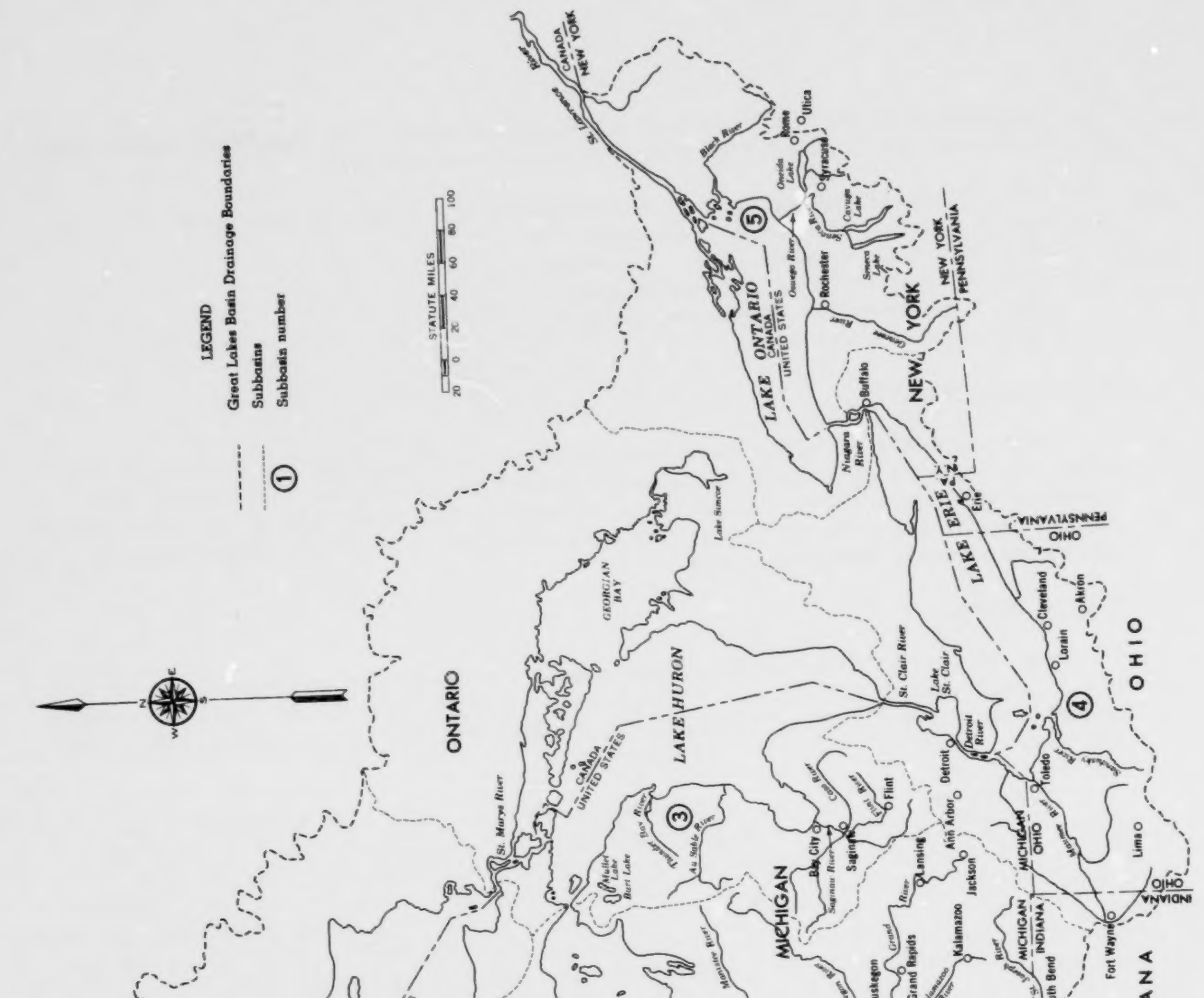

LEGEND
Great Lakes Basin Drainage Boundaries
Subbasins
Subbasin number
STATUTE MILES
20
0
20
40
60
80
100
N
S
E
W
ONTARIO
MINNESOTA
CANADA
MINNESOTA
MINNESOTA
WISCONSIN
Duluth
Superior
St. Louis River
LAKE SUPERIOR
CANADA
UNITED STATES
1
MICHIGAN
MICH.
WIS.
WISCONSIN
Menominee River
Manistique River
Oconto River
Wolf
Fox River
Lake Winnebago
GREEN BAY
Green Bay
Milwaukee
Racine
Kenosha
WISCONSIN
ILLINOIS
ILLINOIS
Chicago
Hammond
Gary
ILLINOIS
INDIANA
2
LAKE MICHIGAN
INDIANA
South Bend
Fort Wayne
INDIANA
OHIO
Lima
St. Marys River
Mullet Lake
Burt Lake
Thunder Bay River
3
Au Sable River
Manistee River
Muskegon River
Muskegon
MICHIGAN
Grand River
Grand Rapids
Kalamazoo River
Kalamazoo
St. Joseph River
MICHIGAN
INDIANA
Saginaw River
Bay City
Saginaw
Flint River
Cass River
Flint
Lansing
Jackson
Ann Arbor
Detroit
MICHIGAN
OHIO
Maumee River
Toledo
Sandusky River
Detroit River
Lake St. Clair
St. Clair River
LAKE HURON
CANADA
UNITED STATES
GEORGIAN BAY
Lake Simcoe
4
OHIO
Lorain
Cleveland
Akron
OHIO
PENNSYLVANIA
LAKE ERIE
Erie
Niagara River
Buffalo
NEW YORK
NEW YORK
PENNSYLVANIA
Genesee River
Rochester
Seneca Lake
Cayuga Lake
Seneca River
Oswego River
Syracuse
Oneida Lake
Rome
Utica
LAKE ONTARIO
CANADA
UNITED STATES
5
Black River
St. Lawrence River
CANADA
NEW YORK

FIGURE 1 Great Lakes Basin

Physical Fabric

Physical fabric information considered important to land drainage/water quality relationships includes geology, soils, minerals, climate, surface and groundwater, and vegetation and wildlife. Demographic and economic characteristics were also considered as they relate to the human adaptation and use of this physical environment.

The U.S. Great Lakes Basin (Figure 1) is located in the eastern portion of the north central United States, with a drainage basin of 461,930 square kilometers (178,350 square miles). The State of Michigan contains 43 percent of the total land area in the region. The Basin is underlain almost entirely by a thick succession of sedimentary rocks. Glacial and alluvial deposits cover the bedrock, with the thickest deposits occurring in Michigan and locally in buried bedrock valleys of New York and Wisconsin. Topography is irregular and varied, including depressions occupied by small lakes or marshes, level to sloping plains, and low rolling hills or ridges. The soils of the Basin vary by area and reflect past and present climatic conditions, natural drainage, vegetative cover, and time interacting with the parent glacial materials. The mineral industry is important to local and national economies. Occurrence and production of the mineral resources depend on the geographic distribution and accessibility of certain formations. Climate of the Basin is continental to semimaritime, with westerly atmospheric circulation. Ground water is present throughout the Basin, with the most productive aquifers in western and central Michigan, northeastern Indiana, and the western part of the Wisconsin area in the Basin. The Great Lakes represent the largest freshwater storage system in the world. The chemical and biological characteristics of the system are undergoing rapid change, particularly in areas of high population concentration. The majority of people in the Basin are concentrated in port and industrial centers along the shores of the Great Lakes or near the junctions of major land and water transportation routes, with northern and inland areas more sparsely populated. Some Basin statistics appear in Tables 1 and 2.

Major Land Uses

Under contract with the U.S. Environmental Protection Agency, the Laboratory for Applications of Remote Sensing (LARS), Purdue University using LANDSAT-1 MSS prepared a current land inventory of the 34,000,000 hectares (84,000,000 acres) included within the U.S. portion of the Great Lakes Basin. Spectrally separable classes related to eight land use categories were developed. Tabulations by each of the 191 counties in the Great Lakes Region were made for the eight categories -- Urban; Residential and Commercial/Industrial, Agriculture; Row Crops, Close Grown Crops and Pasture and Meadows, Forest; and No Major Usage; and Water and Wetlands.

Specialized Land Uses

The specialized land uses covered in this report are disposal operations, erosion, intensive livestock operations, high-density nonsewered residential areas, and recreational lands. These categories are considered to be the more

TABLE 1 Counties in the Great Lakes Region by Plan Area and Planning Subarea

LAKE SUPERIOR--PLAN AREA 1.0

PSA 1.1--L. Superior West

- MINNESOTA
  - Carlton
  - Cook
  - Lake
  - St. Louis
- WISCONSIN
  - Ashland
  - Bayfield
  - Douglas
  - Iron

PSA 1.2--L. Superior East

- MICHIGAN
  - Alger
  - Baraga
  - Chippewa
  - Gogebic
  - Houghton
  - Keweenaw
  - Luce
  - Marquette
  - Ontonagon

LAKE MICHIGAN--PLAN AREA 2.0

PSA 2.1--L. Michigan NW

- MICHIGAN
  - Dickinson
  - Iron
  - Menominee
- WISCONSIN
  - Brown
  - Calumet
  - Door
  - Florence
  - Fond du Lac
  - Forest
  - Green Lake
  - Kewaunee
  - Langlade
  - Manitowoc
  - Marinette
  - Marquette
  - Menominee
  - Oconto
  - Outagamie
  - Shawano
  - Sheboygan
  - Waupaca
  - Waushara
  - Winnebago

PSA 2.2--L. Michigan SW

- ILLINOIS
  - Cook
  - Du Page
  - Kane
  - Lake
  - McHenry
  - Will

PSA 2.2 continued

- INDIANA
  - Lake
  - La Porte
  - Porter
  - Starke
- WISCONSIN
  - Kenosha
  - Milwaukee
  - Ozaukee
  - Racine
  - Walworth
  - Washington
  - Waukesha

PSA 2.3--L. Michigan SE

- INDIANA
  - Elkhart
  - Lagrange
  - Marshall
  - Noble
  - St. Joseph
  - Steuben
- MICHIGAN
  - Allegan
  - Barry
  - Berrien
  - Branch
  - Calhoun
  - Cass
  - Clinton
  - Eaton
  - Hillsdale
  - Ingham
  - Ionia
  - Jackson
  - Kalamazoo
  - Kent
  - Montcalm
  - Ottawa
  - St. Joseph
  - Shiawassee
  - Van Buren

PSA 2.4--L. Michigan NE

- MICHIGAN
  - Antrim
  - Benzie
  - Charlevoix
  - Delta
  - Emmet
  - Grand Traverse
  - Kalkaska
  - Lake
  - Leelanau
  - Mackinac
  - Manistee
  - Mason
  - Mecosta
  - Missaukee
  - Muskegon
  - Newaygo
  - Oceana
  - Osceola

PSA 2.4 continued

- Schoolcraft
- Wexford

LAKE HURON--PLAN AREA 3.0

PSA 3.1--L. Huron North

- MICHIGAN
  - Alcona
  - Alpena
  - Arenac
  - Cheboygan
  - Crawford
  - Iosco
  - Montmorency
  - Ogemaw
  - Oscoda
  - Otsego
  - Presque Isle

PSA 3.2--L. Huron Central

- MICHIGAN
  - Bay
  - Clare
  - Genesee
  - Gladwin
  - Gratiot
  - Huron
  - Isabella
  - Lapeer
  - Midland
  - Saginaw
  - Tuscola

LAKE ERIE--PLAN AREA 4.0

PSA 4.1--L. Erie NW

- MICHIGAN
  - Lenawee
  - Livingston
  - Macomb
  - Monroe
  - Oakland
  - St. Clair
  - Sanilac
  - Washtenaw
  - Wayne

PSA 4.2--L. Erie SW

- INDIANA
  - Adams
  - Allen
  - De Kalb
- OHIO
  - Allen
  - Auglaize
  - Crawford
  - Defiance
  - Erie
  - Fulton
  - Hancock
  - Henry
  - Huron

PSA 4.2 continued

- Lucas
- Mercer
- Ottawa
- Paulding
- Putnam
- Sandusky
- Seneca
- Van Wert
- Williams
- Wood
- Wyandot

PSA 4.3--L. Erie Central

- OHIO
  - Ashtabula
  - Cuyahoga
  - Geauga
  - Lake
  - Lorain
  - Medina
  - Portage
  - Summit

PSA 4.4--L. Erie East

- PENNSYLVANIA
  - Erie
- NEW YORK
  - Cattaraugus
  - Chautauqua
  - Erie
  - Niagara

LAKE ONTARIO--PLAN AREA 5.0

PSA 5.1--L. Ontario West

- NEW YORK
  - Allegany
  - Genesee
  - Livingston
  - Monroe
  - Orleans
  - Wyoming

PSA 5.2--L. Ontario Central

- NEW YORK
  - Cayuga
  - Herkimer
  - Madison
  - Oneida
  - Onondaga
  - Ontario
  - Oswego
  - Schuyler
  - Seneca
  - Tompkins
  - Wayne
  - Yates

PSA 5.3--L. Ontario East

- NEW YORK
  - Jefferson
  - Lewis
  - St. Lawrence

TABLE 2 GREAT LAKES AREA MEASUREMENT (area in square miles)[1]

	Drainage Basin (land & water)			Water Surface			Land Surface		
	U.S.	Canada	Total	U.S.	Canada	Total	U.S.	Canada	Total
Lake Superior	37,500	43,500	81,000	20,600	11,100	31,700	16,900	32,400	49,300
Lake Michigan	67,900	0	67,900	22,300	0	22,300	45,600	0	45,600
Lake Huron	25,300	49,500	74,800	9,100	13,900	23,000	16,200	35,600	51,800
Lake St. Clair	2,370	4,150	6,520	162	268	430	2,208	3,882	6,090
Lake Erie	23,600	9,880	33,500	4,980	4,930	9,910	18,620	4,950	23,600
Lake Ontario	16,800	15,300	32,100	3,460	3,880	7,340	13,340	11,420	24,700
Total to Lake Ontario Outlet	173,470	122,330	295,800	60,602	34,078	94,680	112,868	88,252	201,100[3/]
Lake Ontario Outlet to Moses-Saunders Dam	1,685[2/]	1,325[2/]	3,010	120[2/]	115[2/]	235	1,565[2/]	1,210[2/]	2,775
Total[3/]	175,200	123,600	298,800	60,720	34,190	94,910	114,430	89,450	203,900
Grass-Raquette-St. Regis	3,200						3,200		
Total Basin Study Area	178,350			60,720			117,630		

[1/] Difference between total basin area and water area.

[2/] Estimated breakdown between U.S. and Canada.

[3/] Rounded.

NOTE: The drainage basin area in both U.S. and Canada, above the mouth of the St. Regis River is approximately 302,000 square miles.

Square Kilometers (sq km) = square miles (sq mi) x 2.59

significant nonpoint sources of pollution affecting the water quality of the Great Lakes.

The categories of specialized land uses vary in numbers and in intensity of use throughout the Basin. The major forms of pollutional residuals are nutrients, sediments, and other chemicals. Nutrient generation results from operations involving liquid, solid, and dredge spoil disposal, as well as the development of high-density nonsewered housing areas. The largest numbers of waste disposal sites are found in the more populous Lake Michigan and Lake Erie basins, with a larger percentage of nonsewered households in the less populous Lake Superior and Huron basins. Other specialized land use, such as livestock operations, generate some amounts of nutrients as well, with the largest number of these operations in the Lake Michigan and Erie basins.

The generation of sediments is due to erosion of lakeshore and riverbanks and to sheet erosion. While it is primarily a natural ongoing process, in certain areas measures could be taken to reduce man-induced erosion. The use of recreation lands in areas of unstable soil can produce significant localized sedimentation. Dredge spoil disposal and artificial fills can affect the quantity of sediments reaching the lake, both through the initial dredging and scouring of harbors and channels, and in the disposal operations, particularly in open lake dumping.

Industrial chemicals result from the leaching of various metals from liquid and solid waste disposal sites, although certain amounts will also leach from dredge spoil operations. Finally, recreational land use will involve some generation of hazardous chemicals due to the application of pesticides to control weeds and insects in these areas, as well as phenols and oils resulting from motorized recreational vehicle and boating use.

Materials Usage

The Materials Usage section addresses primarily agricultural operations. However, an additional category, road salts, has been incorporated into the section to address the influences of road deicing salting practices upon the water quality of the Great Lakes. Materials usage varies widely throughout the Basin, depending upon the type of agricultural production in the area and upon climatic conditions.

The major residuals generated from the various materials used in agricultural operations are nutrients and industrial chemical materials. The generation of nutrients, primarily nitrogen and phosphorus, results from animal manures and fertilizer usage. Chemical residual materials are primarily generated from the use of herbicides, insecticides, and fungicides on crops. In addition, road deicing salts can generate significant levels of chloride concentrations in localized ground and surface water areas. Another component, although relatively modest in magnitude, is the leaching of liming materials into ground and surface water areas.

Future Trends

Due to the urban-industrial concentrations in the Basin, both the demographic and economic trends for the Great Lakes Basin closely follow the national trends. Two alternative futures were developed and utilized based on the 1972 revised OBERS Series C and Series E national economic and demographic projections. Changes in specialized land uses and materials usage are not directly dependent upon economic and demographic trends. Specialized land use trends depend, in addition, upon available technologies, land characteristics, and specific economic factors which many times are not related to the larger regional economy. The wide diversity of land forms, land uses, and population concentrations in the Great Lakes Basin leads to moderate to severe local impacts.

PHYSICAL FABRIC

THE GREAT LAKES BASIN

The physical setting of the Great Lakes Basin has influenced the cultural development of the Basin, including the economic activities carried on, the number of people who live in the Basin, and the distribution of the population. The most significant single element in this physical setting is the five Great Lakes, the largest series of freshwater bodies in the world (Table 3). This unique water feature, coupled with the mineral resources of the Basin and the agricultural opportunities afforded by the land, has produced a highly developed industrial and agricultural area, supporting 14 percent of the population of the United States in 4 percent of the area, and contributing far more than its share to the country's economic activity.

The U.S. Great Lakes Basin is located in the eastern portion of the north central United States along the boundary with Canada between 40°30' and 48°20' north latitude and 74°30' and 93°10' west longitude. The Basin extends nearly 1450 kilometers (900 miles) from west to east and 845 kilometers (525 miles), between its north-south extremes. It contains portions of eight states, including Minnesota, Wisconsin, Michigan, Indiana, Illinois, Ohio, Pennsylvania, and New

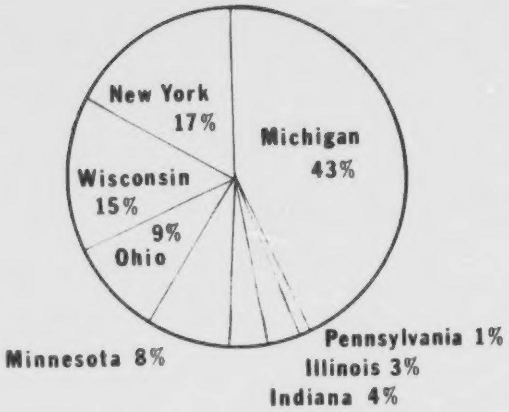
TABLE 3 Great Lakes Surface Area, U.S. and Canada

	Area in Square Miles	World Ranking (Freshwater)
Lake Superior	31,700	1
Lake Huron	23,000	4
Lake Michigan	22,300	5
Lake Erie	9,910	11
Lake Ontario	7,340	14
TOTAL	94,250	

Square Kilometer (sq km) = Square Miles (sq mi) x 2.59

York. For planning purposes, the Basin is divided into five major areas, one for each of the five Great Lakes. Those counties bordering on or draining into Lake Superior are in Plan Area 1.0; similarly, Lake Michigan counties are in 2.0; Lake Huron, 3.0: Lake Erie 4.0; and Lake Ontario, 5.0 (Figure 2).

Each Lake basin plan area is further divided into planning subareas (PSAs) as follows: Plan Area 1.0 is divided into PSAs 1.1 and 1.2; Plan Area 2.0 into PSAs 2.1, 2.2, 2.3, and 2.4; Plan Area 3.0 into PSAs 3.1 and 3.2; Plan Area 4.0 into 4.1, 4.2, 4.3, and 4.4; and Plan Area 5.0 into PSAs 5.1, 5.2, and 5.3 (Figure 3). The subareas include 191 counties. Table 1 lists the counties involved in this study.



State	Total Area in Region (1,000,000 acres)
Michigan	37.3
New York	14.3
Wisconsin	13.2
Ohio	7.8
Minnesota	7.3
Indiana	3.7
Illinois	2.4
Pennsylvania	0.5
Total Area in Region	86.5

Figure 2 Percentage of Total Region Area in Each State

LAND RESOURCES

Geology, Physiography, and Topography

Most of the rock formations that underlie the Great Lakes Basin were formed within the last half-billion years--since the end of Precambrian times. In Paleozoic times (500 million to 250 million years ago) the Basin was covered by shallow saline seas filled with aquatic life. Sediment from these seas formed the bedrock deposits of limestone, dolomite, other carbonates, sandstones, and shales which characterize the Basin.

The Great Lakes Basin is underlain almost entirely by a thick succession of sedimentary rocks. The major structures include the large Michigan basin and a long, narrow structural platform, extending from Indiana to the St. Lawrence Valley. Crystalline rocks extrude in the western Lake Superior and Adirondack regions and from a buried structural high separating the sedimentary basin and platform structures.

Glacial and alluvial deposits cover the bedrock. These deposits are as much as 335 meters (1,100 feet) thick, with the thickest deposits generally occurring in Michigan and locally in buried bedrock valleys of New York and Wisconsin. The deposits are thin or nonexistent on bedrock surfaces in the southern part of the Basin and in bedrock highs of Minnesota, New York, and Wisconsin. The deposits range in composition from clay and silt, through

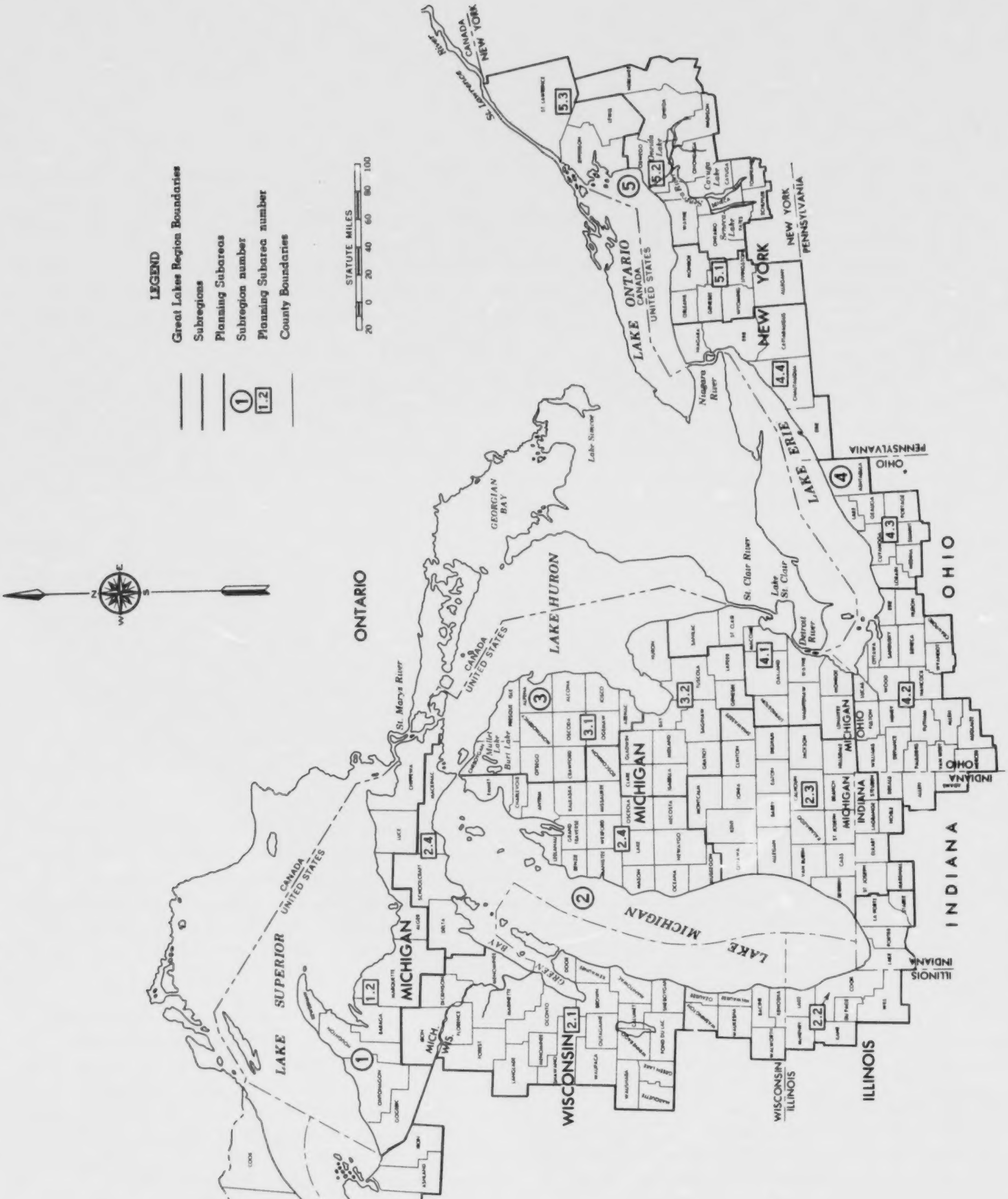

LEGEND
Great Lakes Region Boundaries
Subregions
Planning Subareas
① Subregion number
1.2 Planning Subarea number
County Boundaries
STATUTE MILES
20 0 20 40 60 80 100
ONTARIO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
GEORGIAN BAY
GREEN BAY
Lake Simcoe
St. Marys River
St. Clair River
Lake St. Clair
Detroit River
Niagara River
St. Lawrence River
Burt Lake
Mullett Lake
Oneida Lake
Cayuga Lake
Seneca Lake
CANADA
UNITED STATES
MINNESOTA
WISCONSIN
MICHIGAN
MICH.
WIS.
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW YORK
1
1.1
1.2
2
2.1
2.2
2.3
2.4
3
3.1
3.2
4
4.1
4.2
4.3
4.4
5
5.1
5.2
5.3

FIGURE 3 Great Lakes Region Planning Subareas

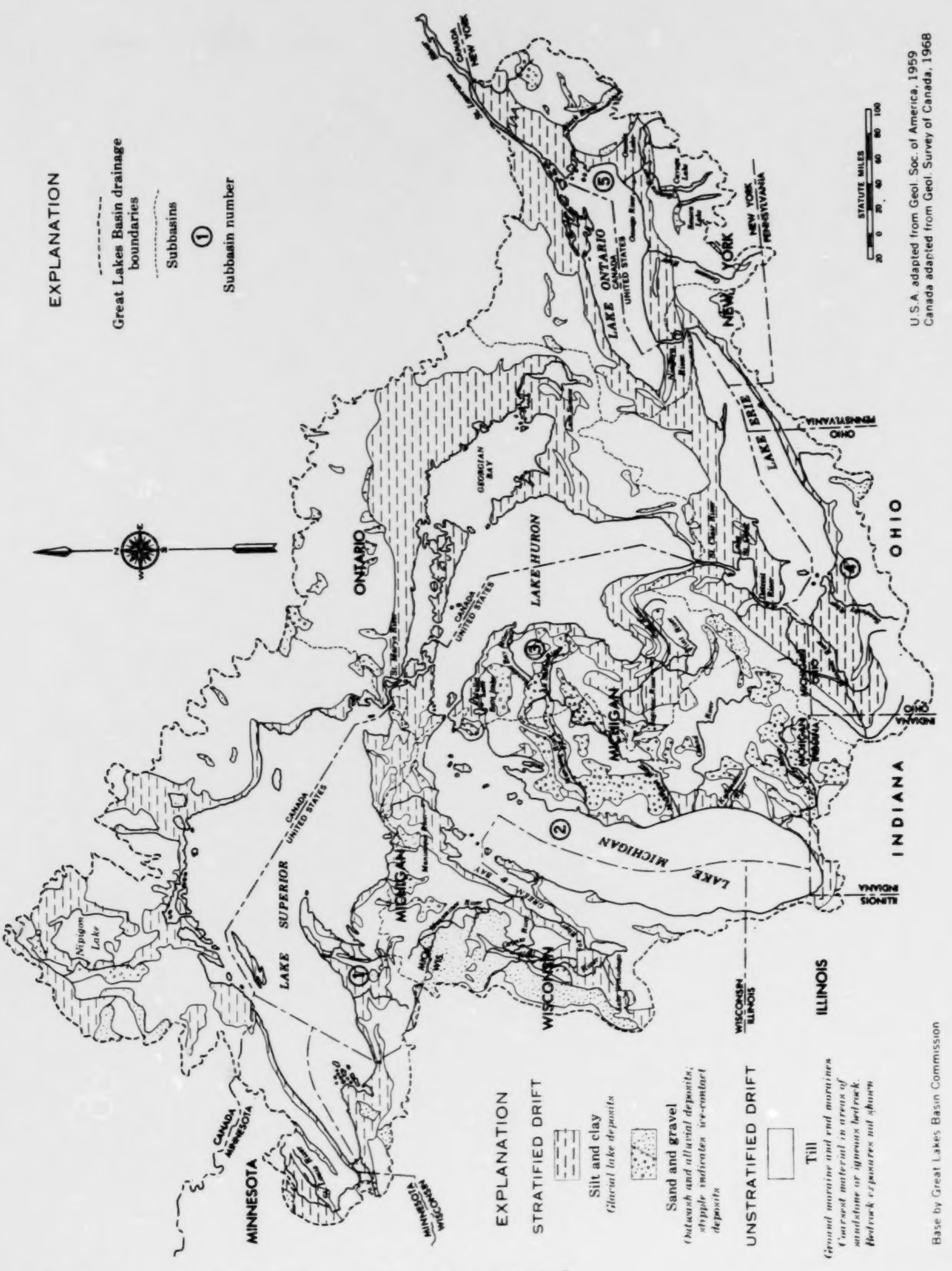
sand and gravel, to boulders which can be well sorted or a heterogeneous mixture. The clay and silt deposits represent the former extent of lakes during deglaciation and generally border the present Great Lakes. The sand and gravel deposits were formed by glacial materials. The size and the extent of these deposits are dependent upon the longevity of the meltwater stream. The glacial till is a heterogeneous mixture deposited by the ice, with little or no sorting action by meltwater. Figures 4 and 5 indicate the glacial geology and bedrock geology in detail.

The areal geology of the Basin provides a separation of the entire Great Lakes drainage basin into three major physiographic provinces (Figure 6). Lake Superior and the northern third of the total Basin are in the Laurentian Uplands Province; the other Lakes and much of the drainage basin are in the Interior Lowlands Province; and minor portions of the drainage basins of Lakes Erie and Ontario are in the Appalachian Plateau Province.

The Laurentian Uplands are characterized by low-lying swamps, poorly drained areas and occasional ranges of hills. Elevations in the region generally range from 183 to 762 meters (600 to 2500 feet). The hills are underlain by resistant rock masses, and the low areas by a thin veneer of glacial debris. For the most part, the Laurentian Uplands coincide with the Canadian Shield. The Interior Lowlands are better drained than the Laurentian Uplands. The major ridges of the Lowlands are glacial moraines and outcrops of resistant, dipping pre-pleistocene strata. Elevations range from 213 to 305 meters (700 to 1000 feet). Examples of the resistant pre-Pleistocene ridges are the Niagara Escarpment in the Niagara Peninsula of New York and Ontario and in the Door Pininsula of Wisconsin.

The southeastern border of the Basin is formed by the Southern New York and Mohawk sections of the Appalachian Plateau Province. The area is a maturely dissected and glaciated plateau of varied relief and prominent escarpments. At the mouth of the Basin, several tributary streams drain the subdued glaciated mountains of the Adirondack Province. The Basin outlet is through the wide St. Lawrence Valley Province, which consists of a young marine plain with local rock hills.

To summarize, the Basin has an irregular and varied topography, including depressions occupied by small lakes or marshes, level to sloping plains, and low rolling hills or ridges. The Region contains thousands of natural lakes and a poorly developed surface drainage system with relatively flat stream profiles. River basin divides are characteristically broad and vary from almost level plains to rolling low hills. Only near the eastern and western ends of the Region is the relief more strongly expressed. Elevations range from approximately 1,400 meters (4,600 feet) above sea level in the Adirondacks of New York to 46 meters (152 feet) above sea level along the St. Lawrence River. Santanoni Peak reaches 1,408 (4,621 feet) above mean sea level. In most of the Basin the land surface is less than 305 meters (1,000 feet) above mean sea level. The highest point in the headwaters area of Lake Superior is 701 meters (2,301 feet) at Eagle Mountain in Cook County, Minnesota.


EXPLANATION
Great Lakes Basin drainage boundaries
Subbasins
① Subbasin number
EXPLANATION
STRATIFIED DRIFT
Silt and clay
Glacial lake deposits
Sand and gravel
Outwash and alluvial deposits; stipple indicates ice-contact deposits
UNSTRATIFIED DRIFT
Till
Ground moraine and end moraines. Coarsest material in areas of sandstone or igneous bedrock. Bedrock exposures not shown
Nipigon Lake
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ERIE
LAKE ONTARIO
CANADA
UNITED STATES
ONTARIO
MICHIGAN
WISCONSIN
MINNESOTA
ILLINOIS
INDIANA
OHIO
NEW YORK
PENNSYLVANIA
①
②
③
④
⑤
STATUTE MILES
20 0 20 40 60 80 100

U.S.A. adapted from Geol. Soc. of America, 1959
Canada adapted from Geol. Survey of Canada, 1968

Base by Great Lakes Basin Commission

FIGURE 4 Glacial Geology of the Great Lakes Basin [2]

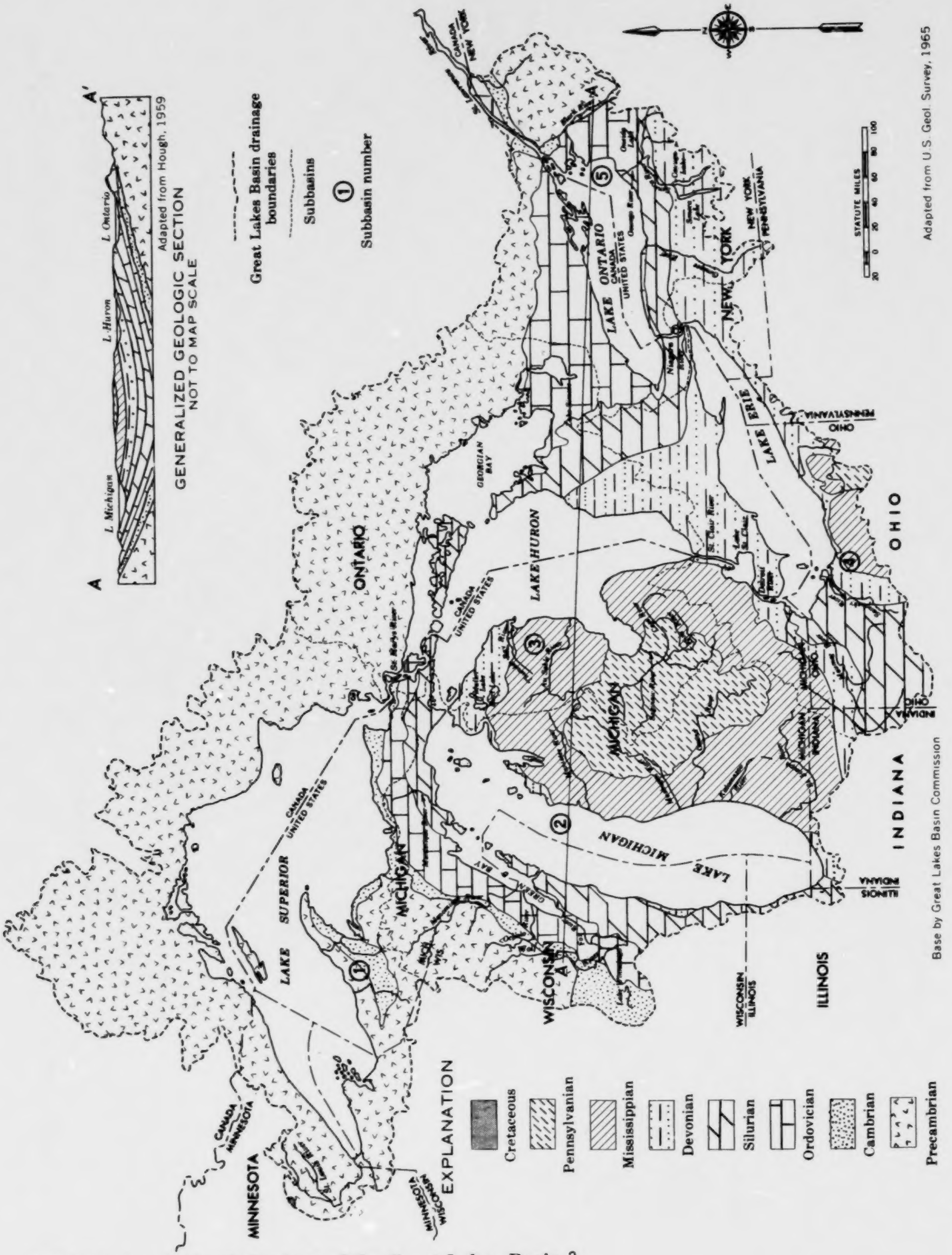
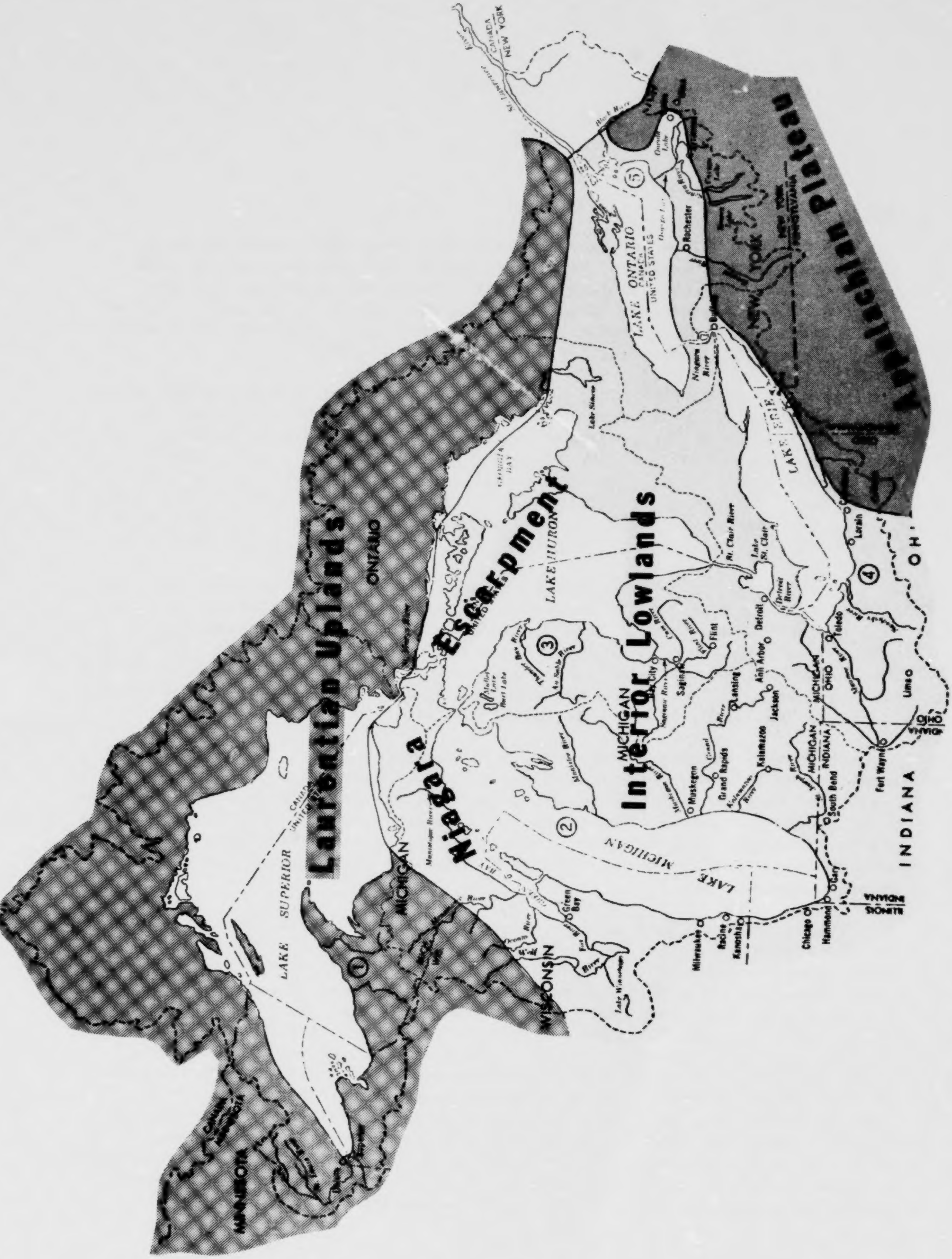

EXPLANATION
Cretaceous
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
Precambrian
GENERALIZED GEOLOGIC SECTION
NOT TO MAP SCALE
Adapted from Hough, 1959
A
A'
L. Michigan
L. Huron
L. Ontario
Great Lakes Basin drainage boundaries
Subbasins
① Subbasin number
STATUTE MILES
20 0 20 40 60 80 100
Adapted from U.S. Geol. Survey, 1965
Base by Great Lakes Basin Commission
MINNESOTA
CANADA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW YORK
ONTARIO
UNITED STATES
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
GEORGIAN BAY
GREEN BAY
①
②
③
④
⑤

FIGURE 5 Bedrock Geology of the Great Lakes Basin[2]



Laurentian Uplands
Niagara Escarpment
Interior Lowlands
Appalachian Plateau
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
GEORGIAN BAY
ONTARIO
MICHIGAN
WISCONSIN
MINNESOTA
INDIANA
OHIO
ILLINOIS
NEW YORK
PENNSYLVANIA
CANADA
UNITED STATES
1
2
3
4
5
Green Bay
Milwaukee
Racine
Kenosha
Chicago
Hammond
Gary
South Bend
Fort Wayne
Muskegon
Grand Rapids
Kalamazoo
Jackson
Lansing
Ann Arbor
Saginaw
Bay City
Flint
Detroit
Toledo
Lorain
Buffalo
Rochester
Lake Winnebago
Lake Simcoe
Lake St. Clair
St. Clair River
Detroit River
Niagara River
Oneida Lake
Black River

FIGURE 6 Physiography of the Great Lakes Region

Soils

The soils of the Great Lakes Basin reflect past and present climatic conditions, natural drainage, vegetative cover, and time interacting with parent glacial material. Almost the entire Basin was glaciated and left with drift that accumulated to depths up to 335 meters (1,100 feet). Lacustrine deposits generally characterize the present lake shoreline areas while organic soils are common in inland swamp and marsh areas.

The soils of the Basin are best described in terms of areal groups which reflect soil origin and composition in terms of management practices. In Minnesota, the Upper Peninsula and northern Lower Peninsula of Michigan, and the related Wisconsin area, the soils are products of cool, moist forest and are light-colored, acid, rather infertile, and low in organic matter. They vary greatly because of differences in parent material. Stones, sands, and gravels are common, and there are swamps and marshes in which organic soils have formed. A small amount of good soil in intermixed with the poor.

In the southern part of this area sands with sandy or gravelly subsoils predominate. Some crops can be grown, but productivity is limited, and the area is best suited to pine forest. There are some gently sloping to flat plains on the shores of Lake Superior in all three states which are relatively smooth, stone-free, usually rich in lime in the subsoil, and thus suitable for limited farming. Most of the rolling uplands have loamy soils. There are a few rocky highlands, like the Porcupine Mountains, in the area.

In eastern Wisconsin and southern Michigan nearly all the soils were formed under forest vegetation and are light in color and low in organic matter except in areas of poor natural drainage. All of the soils in these two areas were heavily glaciated. Most of the soils usually are quite acid, with liming and fertilization with phosphorus and potassium necessary for crop production. Soil drainage, both internal and surface drainage, is required for efficient economic operations.

The area of northern Indiana, eastern Illinois, northwestern Ohio, and extreme southern Michigan has been heavily glaciated. The soils that were formed (mostly under forest vegetation and generally light in color and low in organic matter, although there are also extensive areas of dark-colored, poorly drained soils) developed from various types of glacial material. These differ considerably in texture. Fine textured soils, such as the Hoytville and Paulding clays, are extensive in the lake plain area of northwestern Ohio. Sands and sandy loam soils occur in northwestern Indiana. Most of the soils in other areas, however, have a friable loam to silt loam surface layer. The land is mostly level to gently rolling, except on moraines and near the main streams, where the soils may be rolling to steep. Much of the land was originally poorly drained; most of it is now in drainage enterprises, but inadequate drainage is still a problem in many areas. Peat and muck soils are rather extensive in northwestern Indiana and are intensively used.

The northeast area of the Basin includes portions of northeastern Ohio, the northern portion of Erie County, Pennsylvania, and northern New York. The soils were derived from parent material that varied from hard crystalline rock to lake-plain sands and clays. Most of the region was covered by glaciers from the north. They mixed older soils with various kinds of rocks, such sandstone, shales, limestones, and clays. Most of the soils are in the gray-brown podzolic group and are quite deficient in lime and phosphorus. The surface horizons are fairly high in organic matter. There is considerable area of more productive soils which developed from calcareous glacial drift south of Lake Ontario in New York. Poor drainage is serious in northeastern Ohio and Erie County, Pennsylvania or where soils have been developed from sandstone or shale. Detailed maps and tables describing the different soils associations are found in the Lake basin volumes of this study.[3]

Minerals

The distribution of the rocks and sediments of each of the three geologic eras represented in the Great Lakes Basin also define the type and location of mineral resources and mineral production within the Basin. Virtually all of the metal resources, including iron, zinc, lead, silver, and copper are found in the Precambrian rocks. Hence, these resources are produced in the northwestern and extreme eastern parts of the Basin in Michigan, Minnesota, and New York. The palezoic rocks contain the mineral fuels of oil, gas, and coal. Nonmetallic minerals, including limestone, dolomite, sandstone, shale, salt, gypsum, and natural brines, are largely found in lower Michigan, Ohio, Illinois, Indiana, and New York. The occurrence and production of these mineral fuels and nonmetals depends on the geographic distribution and accessibility of certain formations. The nonmetal deposits of sand and gravel, clay, marl, and peat found throughout the Basin are contained in the unconsolidated Cenozoic sediments.

Geographic distribution of principal mineral resources produced in each PSA of the Basin is shown in Figure 7. The mineral industry of the Great Lakes Region is important to local and national economies. Total value of mineral production approached 1.5 billion dollars in 1968. The Region's mineral industry also plays a strategic role by supplying 100 percent of the iodine, 69 percent of the iron ore, 51 percent of the magnesium compounds, and 42 percent of the peat, lime, and bromine produced in the United States. Other mineral products are important in the more limited regional and local markets.

CLIMATE

In general, the Great Lakes Basin experiences a continental to semimaritime climate which is large determined by westerly atmospheric circulation (cyclonic storm), its latitudinal position (between 40°30' and 48°20'), and the modifying influence of the Great Lakes upon local atmospheres. Climate over the region is normally humid throughout the year, with cold winters and cool summers in the north and warm summers in the south. Average annual frost-free season is about six months at the southern extremity.

Prevailing winds in the Great Lakes area are from the west, although winds do blow from any sector. During winter, winds of highest frequency of occurrence

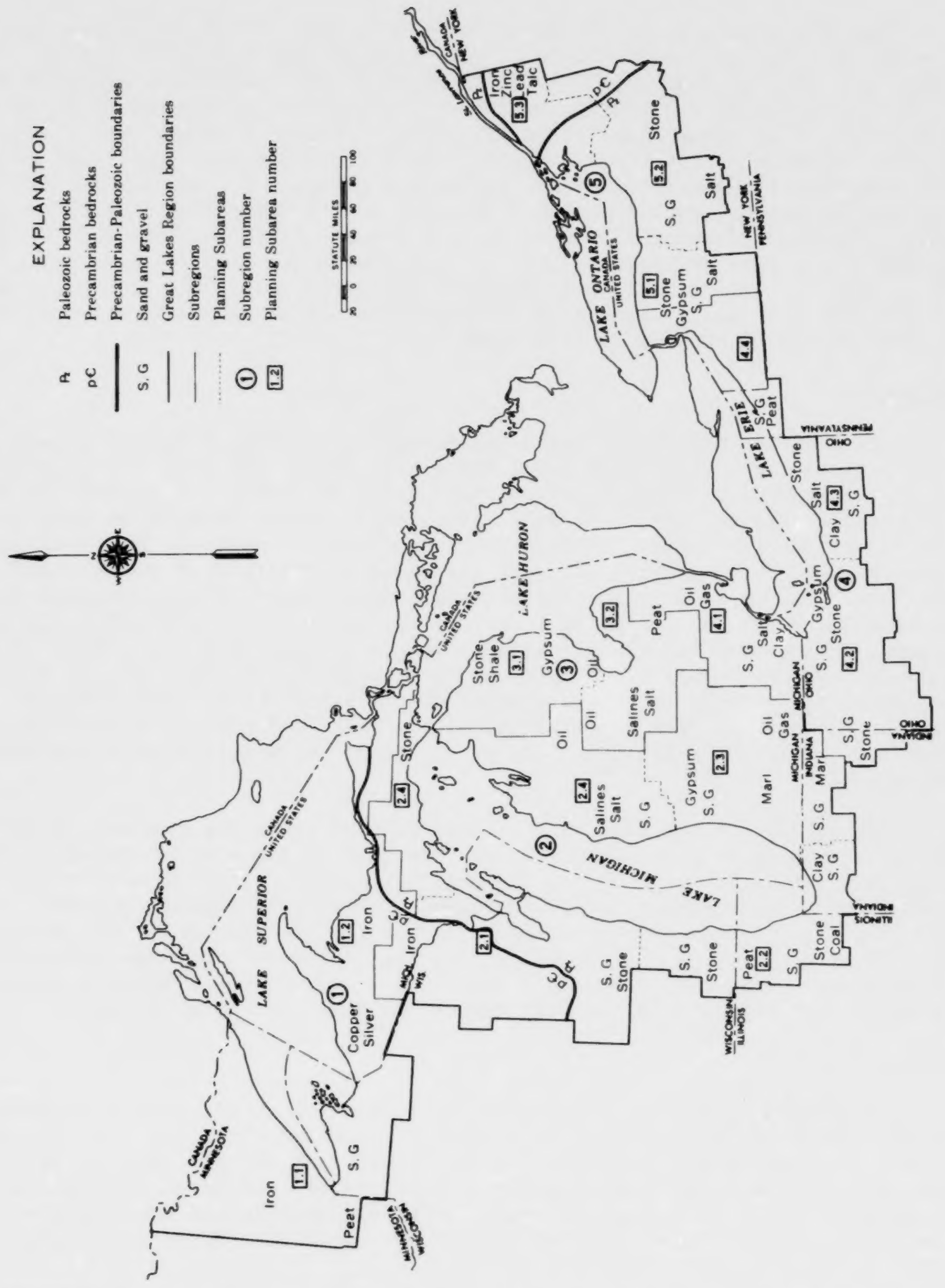

EXPLANATION
Pz Paleozoic bedrocks
pC Precambrian bedrocks
Precambrian-Paleozoic boundaries
S, G Sand and gravel
Great Lakes Region boundaries
Subregions
Planning Subareas
① Subregion number
1.2 Planning Subarea number
STATUTE MILES
20 0 20 40 60 80 100
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
CANADA
UNITED STATES
CANADA MINNESOTA
MINNESOTA WISCONSIN
MICH. WIS.
WISCONSIN ILLINOIS
ILLINOIS INDIANA
MICHIGAN INDIANA
INDIANA OHIO
MICHIGAN OHIO
OHIO PENNSYLVANIA
NEW YORK PENNSYLVANIA
CANADA NEW YORK
St. Lawrence
Iron
Peat
S. G
Copper
Silver
Stone
Coal
Clay
Marl
Gypsum
Salines
Salt
Oil
Gas
Shale
Zinc
Lead
Talc
1.1
1.2
2.1
2.2
2.3
2.4
3.1
3.2
4.1
4.2
4.3
4.4
5.1
5.2
5.3
①
②
③
④
⑤

FIGURE 7 Great Lakes Region: Distribution of Bedrock Geology and Principal Mineral Production[4]

and magnitude are from the west in the western half of the Basin. In the eastern half of the Basin winter winds are most frequently from the west, southwest and northwest. Summer winds are usually from the southwest and south throughout the Basin. There is a strong tendency for maximum wind vectors to be aligned with the long axes of the Lakes.

Mean annual surface air temperature over the Basin range from about 4°C (39°F) on Lake Superior to about 9°C (49°F) on Lake Erie. Minimum and maximum monthly temperatures occur in February and July, respectively, on all the Great Lakes (Figure 8). Differences in latitude cause a decrease in average monthly temperatures of about 5.5°C (10°F) from south to north. The surface of the Great Lakes, which comprises about one-third of the area of the Basin, acts as a medium for heat exchange between the water masses and the atmosphere. The Lakes tend to moderate temperature differences in adjacent land areas. Thus, the interiors of Michigan's upper and lower peninsulas are colder than equivalent coastal areas at similar latitudes.

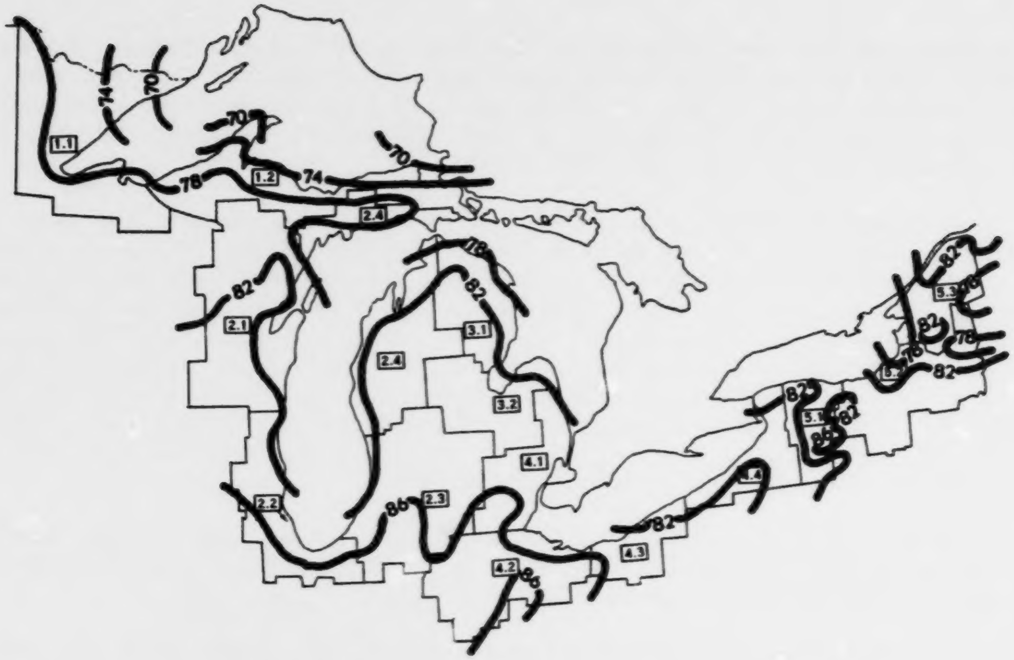
Short-term local variations in surface air temperatures can be extreme. It is not unusual for intense cells of cold arctic air to decrease temperature as much as 27.7°C (50°F) in one day.

In addition to moderating air temperatures, the Great Lakes also change Basin humidity by contributing thousands of tons of moisture through evaporation. Estimates of the annual rate of evaporation on the surface of the Great Lakes range fraom a minimum of about 0.5 meters (1.5 feet) on Lake Superior to about 0.9 meters (3.0 feet) on Lake Erie. On an annual average the Great Lakes increase the humidity of the Basin on the order of 15 percent.

Annual precipitation over most of the Great Lakes Basin, including rainfall, snow, and less important modes of transfer of water from the atmosphere to the earth surface, ranges from less than 71 to over 94 centimeters (less than 28 to over 37 inches). In the southeastern and eastern portions of the Basin, the Adirondack Mountains, and the Allegheny Plateau, the total annual precipitation increases to over 119 centimeters (47 inches). The relative uniformity of precipitation over a large area is due to the lack of major topographic variation in the Basin and the uniformity of exogenous weather (Figure 9). Increases in precipitation on the southeastern edge of the Basin are caused by the higher elevations of those areas. Annual snowfall ranges from about 102 centimeters to 305 centimeters (40 inches to 120 inches).

Precipitation decreases somewhat from south to north and from east to west. Precipitation decreases with increased latitude because the colder atmosphere at high latitudes does not contain as much moisture as the warmer, southern atmosphere. The west-to-east precipitation increase is caused by the interaction of the Lakes (moisture sources), the prevailing westerly winds, and Basin configuration. The prevailing exogenous winds contain reduced moisture content after having crossed the plains. They receive moisture from the Lakes and precipitation amounts increase toward the east. The Allegheny and Adirondack highlands trigger orographic precipitation in the eastern portions of the Basin.

Seasonally, the lake effect influences precipitation patterns in the Basin.


74
70
1.1
70
70
1.2
74
78
2.4
78
82
82
2.1
3.1
2.4
3.2
4.1
2.2
86
2.3
82
4.4
4.2
86
4.3
5.1
82
86
82
5.2
78
82
78
82
5.3
82
78

Mean Maximum Temperature (°F), July

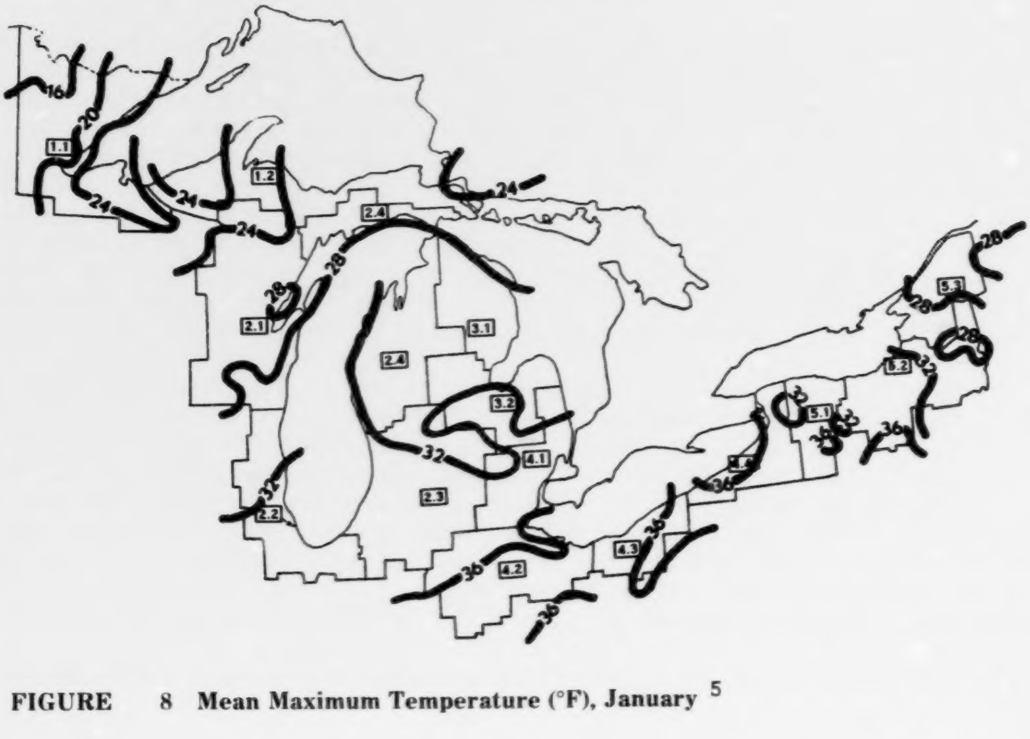

16
20
1.1
24
24
24
1.2
24
2.4
28
28
2.1
3.1
2.4
3.2
32
4.1
2.3
32
2.2
36
4.2
36
4.3
36
4.4
5.1
36
32
5.2
28
5.3
28
28

FIGURE 8 Mean Maximum Temperature (°F), January [5]

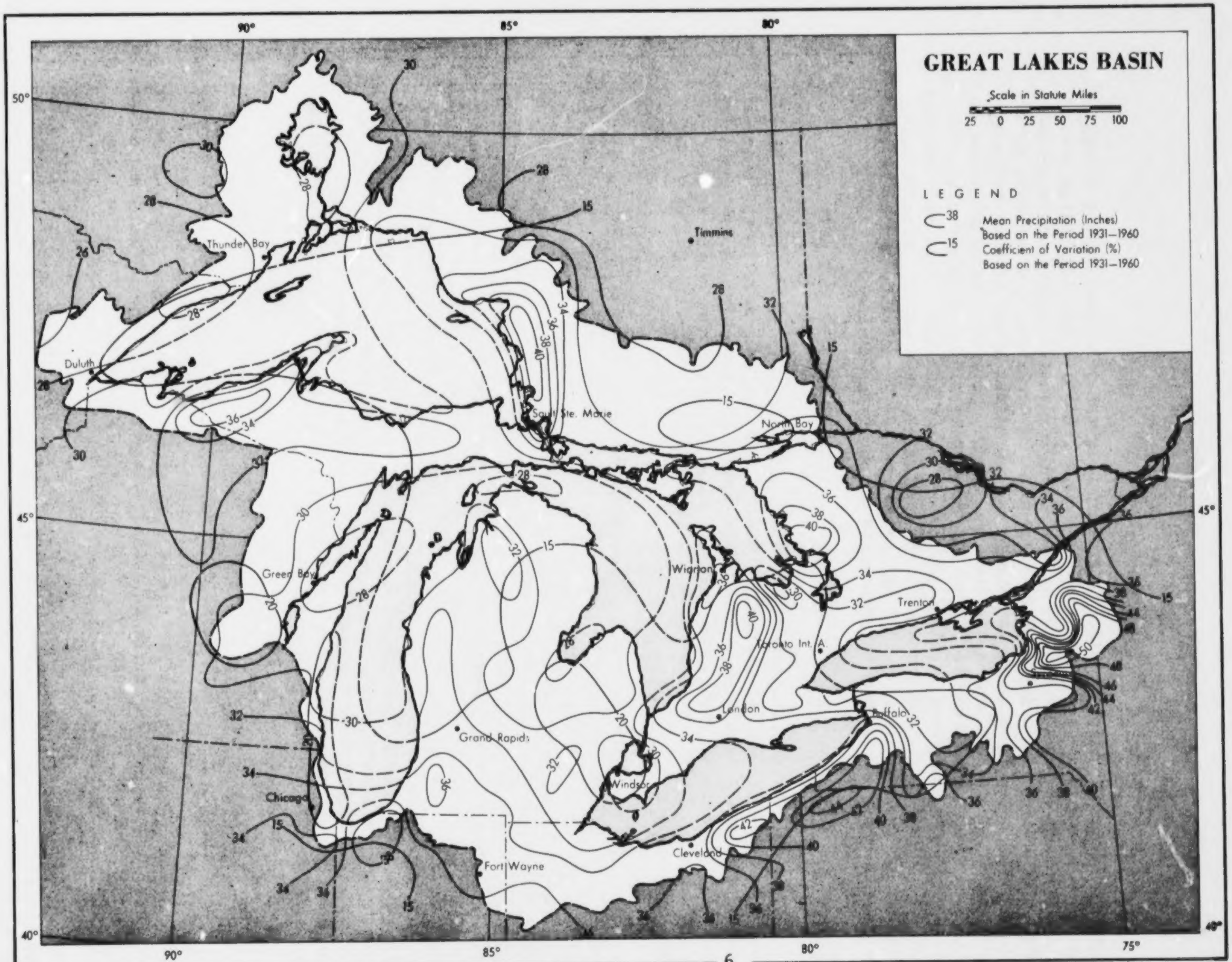

GREAT LAKES BASIN
Scale in Statute Miles
25 0 25 50 75 100
LEGEND
38 Mean Precipitation (Inches) Based on the Period 1931–1960
15 Coefficient of Variation (%) Based on the Period 1931–1960
90°
85°
80°
75°
50°
45°
40°
Thunder Bay
Duluth
Timmins
Sault Ste. Marie
North Bay
Green Bay
Wiarton
Trenton
Toronto Int. A
London
Buffalo
Grand Rapids
Windsor
Chicago
Cleveland
Fort Wayne

Fig. 9 – **MEAN ANNUAL PRECIPITATION (INCHES) AND ITS COEFFICIENT OF VARIATION (%). Precipitation increases southeastward from a low of 28 inches in Minnesota to a high of 52 inches in the Adirondacks of New York state. Other smaller maxima may result from urban effects and topographic control on the leeward side of the Great Lakes, where the water equivalent of winter precipitation may exceed summer rainfall. The coefficient of variation is small averaging 15 per cent across the basin.**

Spring and summer precipitation is greater over the land than over the Lakes and toward coastal areas. Conversely, winter precipitation is greater over the Lakes and coastal areas than inland. These climatic factors have an important effect on the distribution of people, agriculture, and industry in the Basin. The population tends to cluster in the milder areas in the southern portions of the Basin, and along the lakeshores. Climatic characteristics of selected cities are given in Figure 10. The climate, and in particular, the amount of rain water and snowfall can affect water quality. Rain and snow may absorb pollutants in the atmosphere and contaminate the water. Precipitation affects water courses via runoff and percolation. Percolation can cause leachate production by infiltration through solid waste disposal sites.

SURFACE AND GROUND WATER

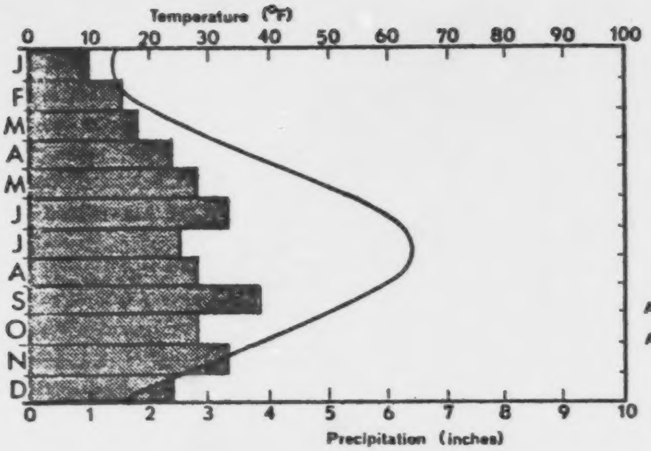
The 246,050 square kilometers (95,000 square miles) of Great Lakes surface area covers 32 percent of the entire Great Lakes drainage area in the United States and Canada (Table 2). Relatively short, immature streams, inland lakes, and minor embayments constitute over 1.2 million hectares or 2,655 square kilometers (2.9 million acrea or 4,500 square miles) of additional surface water in the Basin.

Surface and subsurface water resources are interconnected and in ample supply over the entire Great Lakes Basin. These water resources are constantly moving through a complex hydrologic cycle, in which water may be stored, be captured and used by local flora and fauna, be evaporated, or be run off without use. Generally speaking, of the water which falls as precipitation over the Basin, about 30 centimeters (12 inches) per year, or 239.2 billion liters (63.2 billion gallons) per day, run off the land into streams, lakes, and ultimately into the Great Lakes. Average annual runoff for major United States tributaries ranges from 23 to 97 centimeters (9 to 38 inches) due to differences in temperature, vegetation, terrain, surficial features, geology, and land use, as well as to differences in annual precipitation distribution. General low topographic relief and surficial glacial deposits encourage infiltration of water, while numerous lakes, marshes, and peat bogs reflect poor development of regional surface drainage systems. Area streams are generally short, and their average annual flows are low for basins of their drainage areas.

Ground Water

Base flow of regional streams is derived largely from ground water sources. Nearly half of the Basin's land area is underlain by aquifers that yield over 0.37 million liters per day per square kilometers (0.25 mgd per square mile). Well yields in the Basin can range upward to as much as 18,925 liters per minute (5,000 gallons per minute) in these areas. Average annual yield from ground water systems in the Basin is estimated at 98 billion liters per day (26 bgd).

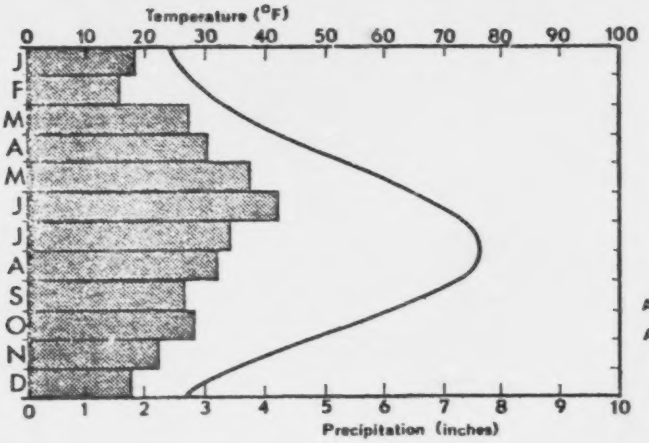
Ground water is present everywhere throughout the Basin, but in limited quantities in areas where the bedrock is at or near the surface (Figure 11). The most productive aquifers occur in unconsolidate, well-sorted sand and gravel deposits, especially where natural recharge from streams or precipitation



Average Monthly
Temperatures and Precipitation for
Sault Ste. Marie, Michigan

Average Annual Temperature: 40.6°F

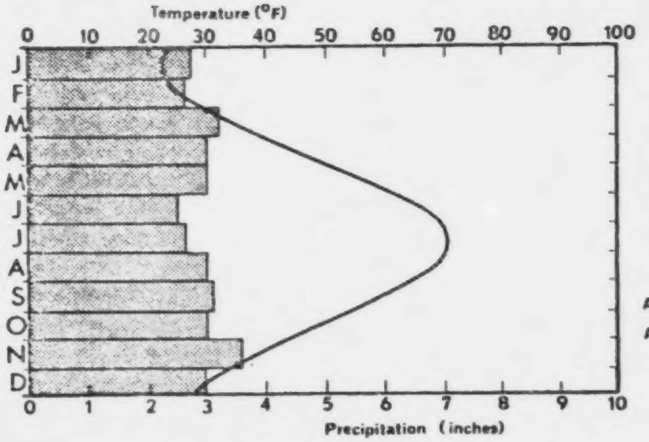
Average Annual Precipitation: 31.2 inches



Average Monthly
Temperatures and Precipitation for
Chicago, Illinois

Average Annual Temperature: 50.8° F

Average Annual Precipitation: 33.2 inches

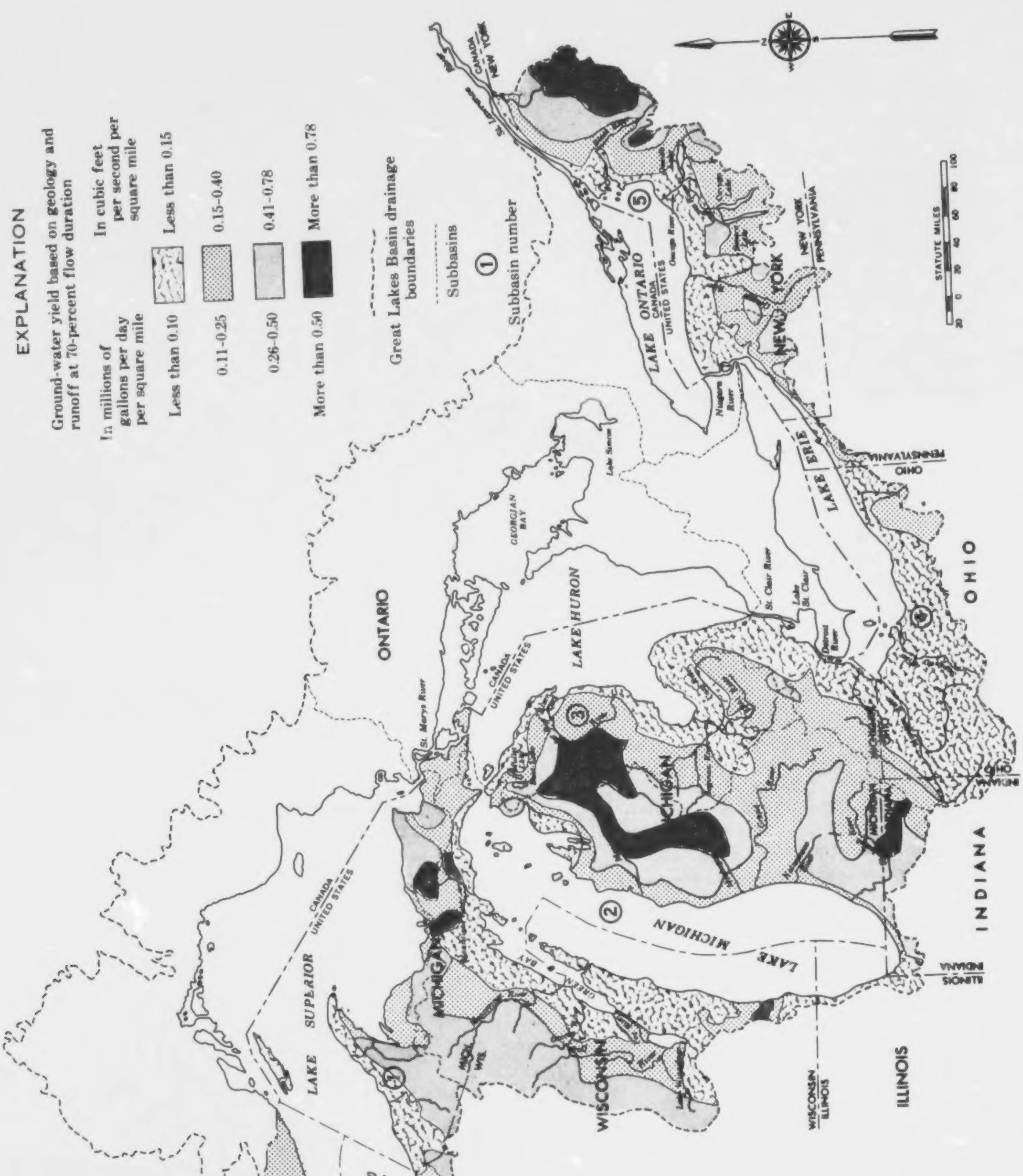


Average Monthly
Temperatures and Precipitation for
Buffalo, New York

Average Annual Temperature: 46.7°F

Average Annual Precipitation: 35.6 inches

FIGURE 10 Climate Characteristics Selected Cities[5]


EXPLANATION
Ground-water yield based on geology and runoff at 70-percent flow duration
In millions of gallons per day per square mile
In cubic feet per second per square mile
Less than 0.10
Less than 0.15
0.11-0.25
0.15-0.40
0.26-0.50
0.41-0.78
More than 0.50
More than 0.78
Great Lakes Basin drainage boundaries
Subbasins
①
Subbasin number
STATUTE MILES
20 0 20 40 60 80 100
ONTARIO
LAKE SUPERIOR
CANADA
UNITED STATES
MINNESOTA
CANADA
MINNESOTA
MINNESOTA
WISCONSIN
MICHIGAN
WISCONSIN
ILLINOIS
WISCONSIN
ILLINOIS
LAKE MICHIGAN
GREEN BAY
ILLINOIS
INDIANA
INDIANA
MICHIGAN
St. Marys River
LAKE HURON
CANADA
UNITED STATES
GEORGIAN BAY
Lake Simcoe
St. Clair River
Lake St. Clair
Detroit River
OHIO
MICHIGAN
OHIO
INDIANA
LAKE ERIE
PENNSYLVANIA
OHIO
Niagara River
LAKE ONTARIO
CANADA
UNITED STATES
NEW YORK
NEW YORK
PENNSYLVANIA
St. Lawrence River
CANADA
NEW YORK
①
②
③
④
⑤
N

Base by Great Lakes Basin Commission

FIGURE 11 Estimated Ground-Water Yield in the Great Lakes Basin [2]

can occur readily. The deposits are most widespread in western and central Michigan, northeastern Indiana, the western part of the Wisconsin area, and locally in the remaining areas.

Bedrock aquifers also vary in their productivity throughout the Basin, but they are more widespread, continuous, and generally more predictable in their potential than unconsolidated aquifers. Carbonate (limestone and dolomite) aquifers constitute the most common bedrock aquifers in the Basin. They occur along the northern and western shore of Lake Michigan, from Illinois to Cleveland, and along the southern shore of Lake Ontario. The carbonates are most productive, with well yields as much as 1,000 gpm, where they extrude or are overlain by unconsolidated deposits. Solution processes have developed good permeability in these areas. Sandstone aquifers are the next most common bedrock aquifers. A thick sequence of productive sandstone units (well yields as much as 1,300 gpm) is present along the western and northern part of the Lake Michigan basin. Such productive units with well yields as much as 500 gpm are also present in parts of Michigan and in Ohio, Pennsylvania, and New York. As aquifers, shale beds are the least productive sedimentary unit. Shales are abundant in the southern part of the Great Lakes Basin from Indiana to the Adirondack Mountains.

Chemical quality of ground water in the Basin is generally good but varies considerably from area to area, depending on the type of aquifer and its depth. Hardness, iron content, and salinity are the most common problems in developing a ground water source. Hard to very hard water generally is present in the carbonate aquifers, in many sandstone aquifers, and in aquifers in unconsolidated deposits that contain carbonate sediments. Excessive iron is very common where the recharge source is relatively close or recharge is rapid. Saline, mineralized, or brackish water containing more than 1,000 mg/l of dissolved solids is present in deep bedrock throughout the Basin. In many areas, highly mineralized water is present at shallow or relatively shallow depths of 75-200 feet. This mineralized water has been in contact with the rocks for a long time or has moved through as easily dissolved rock, such as gypsum, and has accumulated excessive minerals. Highly mineralized water is seldom present in surficial unconsolidated sediments, except locally in New York, Pennsylvania, and Michigan. In these situations, the mineralized water usually has migrated upward from bedrock sources.

The most critical region for highly mineralized water is the Saginaw Bay area of Michigan, where saline water is present in most bedrock aquifers and even in much of the unconsolidated sediments. Saline water is present in relatively shallow (less than 200 feet) bedrock aquifers in the region from Gary, Indiana, to Oneida Lake, New York. Elsewhere, central Michigan, parts of upper Michigan, and the western Lake Superior area have saline aquifers at relatively shallow depths. Most of these areas have freshwater aquifers present in overlying sand and gravel deposits.

Natural ground water discharge or runoff was used to estimate basin yield as a means of determining the ground water potential of the Basin. Ground water runoff with any evapotranspiration that can be salvaged represents the "perennial yield" of a basin. The greatest ground water potential based on runoff lies in north-central Michigan and in the Adirondack Mountains. In these areas, and locally elsewhere, thick sand and gravel deposits with appreciable available recharge make very productive aquifers. The areas with the least yield are along parts of the western shores of Lake Michigan and Lake Superior, and along the southern shores of Lakes Huron, Erie, and Ontario.

Surface Water

The Great Lakes represent the greatest freshwater storage system in the world. Waters from Lake Superior, Lake Michigan, and the Georgian Bay all drain into Lake Huron. The sole natural outlet of these basins is to Lake Huron, and Lake Huron transmits the water supply from these other basins, as well as its own supply, to Lake Erie through the St. Clair River, Lake St. Clair, and the Detroit River. Lake Erie in turn transmits all of this water, plus the contribution of its own basin, through the Niagara River to Lake Ontario. The Ontario outlet is the head of the St. Lawrence River.

There is a progressive drop in surface elevation through the series of Lakes (Figure 12). Seven meters (22 feet) in elevation separate Lake Superior and Lake Huron. Lake Huron and Lake Michigan are one large reservoir at the same level. Two meters (8 feet) in elevation separate Lakes Huron and Erie.

The elevations of the water surface of the Great Lakes are tied to the mean sea level at Father Point, Quebec, on the Gulf of St. Lawrence. This plane of reference, established especially for the Great Lakes, is called the International Great Lakes Datum (1955). The average monthly and annual Lake levels for the 33-year period, 1937-69, are given in Table 4. These levels are based on mean Lake level tabulations published by the Lake Survey, and represent records from a single master gage located at strategic points on each Lake. Approximate water surface elevations of Lakes are 183 meters (601 feet), 176 meters (578 feet), 174 meters (570 feet), and 75 meters (245 feet) for Lakes Superior, Michigan-Huron, Erie, and Ontario respectively.

On Lakes Superior, Michigan, and Huron the normal range in monthly mean water levels from winter low to summer high is only one foot; on Lake Erie, approximately one and one-quarter feet; and on Lake Onterio, one and one-half feet. Since 1860 the monthly levels of Lake Superior from extreme low to extreme high have varied four feet; for Lakes Michigan, Huron and Ontario, the range has been six and one-half feet; and for Lake Erie, five and one-quarter feet.

Long-term Great Lakes level fluctuations and discharge variations are a major problem. Variation effects of the Lakes are minimized by regulation on Lakes Superior and Ontario. However, significant damage and lost economic opportunity arise from lake level fluctuations. Abnormally high levels cause flooding and erosion damage to shorelines and structures. During abnormally low level periods, less draft is available to commercial navigation resulting in higher shipping costs; flows decrease in connecting channels to decrease hydroelectric power generation; fish and wildlife habitat is exposed and threatened; recreation craft are excluded from canals and waterways; and recreational values

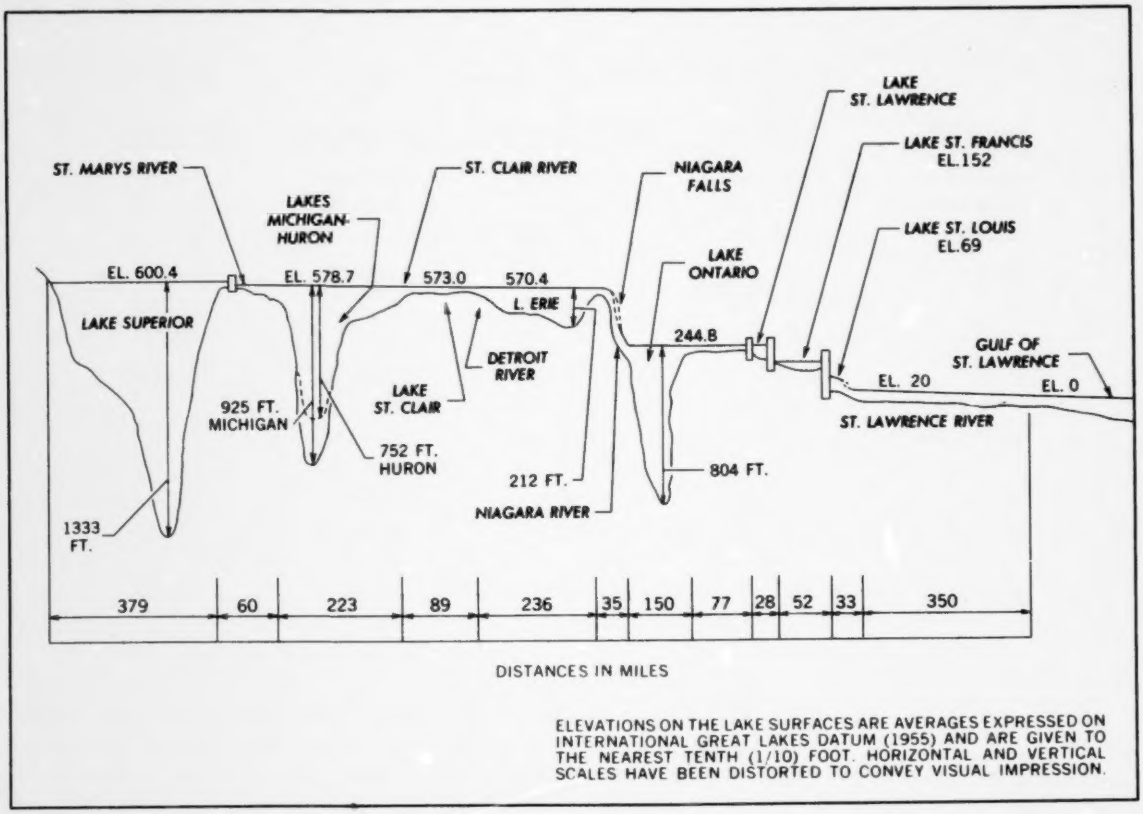

ST. MARYS RIVER
LAKES MICHIGAN-HURON
ST. CLAIR RIVER
NIAGARA FALLS
LAKE ST. LAWRENCE
LAKE ST. FRANCIS EL.152
LAKE ST. LOUIS EL.69
LAKE ONTARIO
EL. 600.4
EL. 578.7
573.0
570.4
L. ERIE
244.8
GULF OF ST. LAWRENCE
EL. 20
EL. 0
LAKE SUPERIOR
DETROIT RIVER
LAKE ST. CLAIR
925 FT. MICHIGAN
752 FT. HURON
212 FT.
804 FT.
NIAGARA RIVER
ST. LAWRENCE RIVER
1333 FT.
379
60
223
89
236
35
150
77
28
52
33
350
DISTANCES IN MILES
ELEVATIONS ON THE LAKE SURFACES ARE AVERAGES EXPRESSED ON INTERNATIONAL GREAT LAKES DATUM (1955) AND ARE GIVEN TO THE NEAREST TENTH (1/10) FOOT. HORIZONTAL AND VERTICAL SCALES HAVE BEEN DISTORTED TO CONVEY VISUAL IMPRESSION.

FIGURE 12 Profile of the Great Lakes System [7]

of water and shoreline are reduced.

Total alkalinity (as $CaCO_3$) ranges from 46 parts per million (ppm) in Lake Superior to 113 ppm in Lake Michigan. The pH ranges from 8.0 to 8.5 for most of the waters, except Lake Superior. Sulfate concentrations are greater than chlorides in the upper Lakes, and sulfates and chlorides are almost equal in Lakes Erie and Ontario. The proportions of calcium, magnesium, and sodium in the upper Lakes are about 10:3:1. Potassium usually averages around 1 ppm in all the Lakes. Silica usually fluctuates around 2-3 ppm, although only trace amounts of silica occur at times in highly productive waters of Lake Erie. Concentrations to total phosphorus are low in the upper Lakes and are usually less than 5 ppm in the open waters of Lake Superior. The phosphorus content of water from Lake Erie is about six times greater than that in the other Lakes. The dissolved oxygen content of much of the Lake water is near saturation, even at the greatest depths, and supersaturation is common. However, dissolved oxygen concentrations of less than 1 ppm have been found in Lake Erie in the bottom waters in an area of several hundred square miles of the central basin.

TABLE 4 Average Levels of the Great Lakes in meters, 1937-1969, IGLD (1955)[7]

Period	Superior at Marquette	Michigan-Huron at Harbor Beach	Erie at Cleveland	Ontario at Oswego
January	183.00	176.01	173.66	74.40
February	182.93	176.01	173.68	74.42
March	182.89	176.02	173.76	74.50
April	182.92	176.09	173.92	74.71
May	183.04	176.19	174.03	74.85
June	183.13	172.26	174.07	74.92
July	183.20	176.32	174.06	74.88
August	183.23	176.30	174.00	74.77
September	183.23	176.25	173.90	74.64
October	183.20	176.19	173.79	74.51
November	183.15	176.13	173.70	74.44
December	183.08	176.08	173.68	74.42
Annual	183.08	176.15	173.85	74.62

The plankton found in the Great Lakes is characteristic of large and deep lakes. Diatoms are the most important constituents of the plankton, although zooplankton may occasionally equal the diatoms in biomass but not in numbers. Blue-green algae are at times especially abundant in Lake Erie and sometimes in Lake Ontario. Even in Lake Erie, however, diatoms usually comprise 75 percent of the phytoplankton.

The chemical and biological characteristics of the Great Lakes system are undergoing rapid change. The Lakes changing the most are those surrounded by the greatest concentrations of human population. Significant increases in the last 40 years in Great Lakes levels of total dissolved solids, largely phosphates, calcium, sodium, sulfates, and chlorides, particularly in Lakes Erie and Ontario, are generally considered to correlate with the rapidly aging aquatic systems.[8]

Quality control problems are becoming serious in areas of high population concentration like Chicago-Gary, Detroit, Cleveland, and Buffalo. Lake Erie and southern Lake Michigan are experiencing accelerated eutrophication as a result of the large quantities of untreated substances entering them. The loss of recreational beaches and fish and wildlife habitat on the Great Lakes and interior lakes and streams illustrates the intensity of growing pollution problems. Waste must be controlled at its source and additional research is required to help answer the many questions posed by the pollution problem. The projected expansion of power facilities in the Basin raises some concern over the dissipation of large quantities of heated water. The kinds and quantities of agricultural substances applied to Basin lands must be carefully scrutinized in light of their potential effects on water quality.

VEGETATION ZONES AND WILDLIFE HABITAT

The natural vegetational pattern of the Great Lakes Region has been greatly modified. Virgin forest lands are almost nonexistent, and much of the once-forested land, especially in the southern portions of the Region, has been replaced by urban, industrial, and agricultural development.

In the areas surrounding Lake Ontario, Lake Erie, southeastern Lake Huron, and southeastern Lake Michigan, the broadleaf deciduous tree (Figure 13), including oaks, hickories, yellow poplar, maples, and 50 or more other species, is the predominant natural vegetation. Southwestern Lake Michigan borders on the eastern edge of the vast interior prairie grasslands. The western portion of the Lake Superior region is covered predominantly with stands of pine and spruce. Between these two major vegetational types (i.e., coniferous on the northwest side of the Region and hardwoods on the south and east) a transition zone is found in which there is a mixture of maple, yellow birch, hemlock, and pine.

Interspersed among these forested lands are bogs. In addition, beach areas support their own distinctive dunal vegetation, including grasses, cedar, balsam fir, and spruce.

Nearly all of the Great Lakes Basin is wildlife habitat. In the U.S. portion of the land area there are 30 million hectares (75 million acres) of habitat or resource base out of a total of 34 million hectares (84 million acres). The shoal waters in the U.S. portion of the Great Lakes total 274,000 hectares (610,000 acres). Of this total, 199,000 hectares (491,000 acres) are important to wildlife. All of the open waters are used from time to time by migrating waterfowl. The value of this habitat varies greatly, but the important consideration is that all nonurbanized land, some urban land, and all waters have some value to wildlife.

The eight kinds of Basin wildlife habitat include northern wilderness forests; farmland woodlots; blocks of eastern hardwood forests; river bottom woodlands; scrub and brush lands; open fields and meadows; cropland; and freshwater wetlands.

As a rule, the supply of wildlife habitat other than cropland is good in the northern and far eastern areas of the Basin and is only fair south of these areas. The country north of the Milwaukee-Buffalo line is forested and sparsely settled, while south of this line the area is heavily settled and is primarily industrial and agricultural. The single most important factor affecting Basin wildlife and habitat is human population growth and the resultant increase in intensity of land use, which causes both degradation and loss of habitat.

The varieties of wildlife that occupy this habitat are diverse, and include big game, waterfowl, shorebirds, wading birds, song birds, small game, and

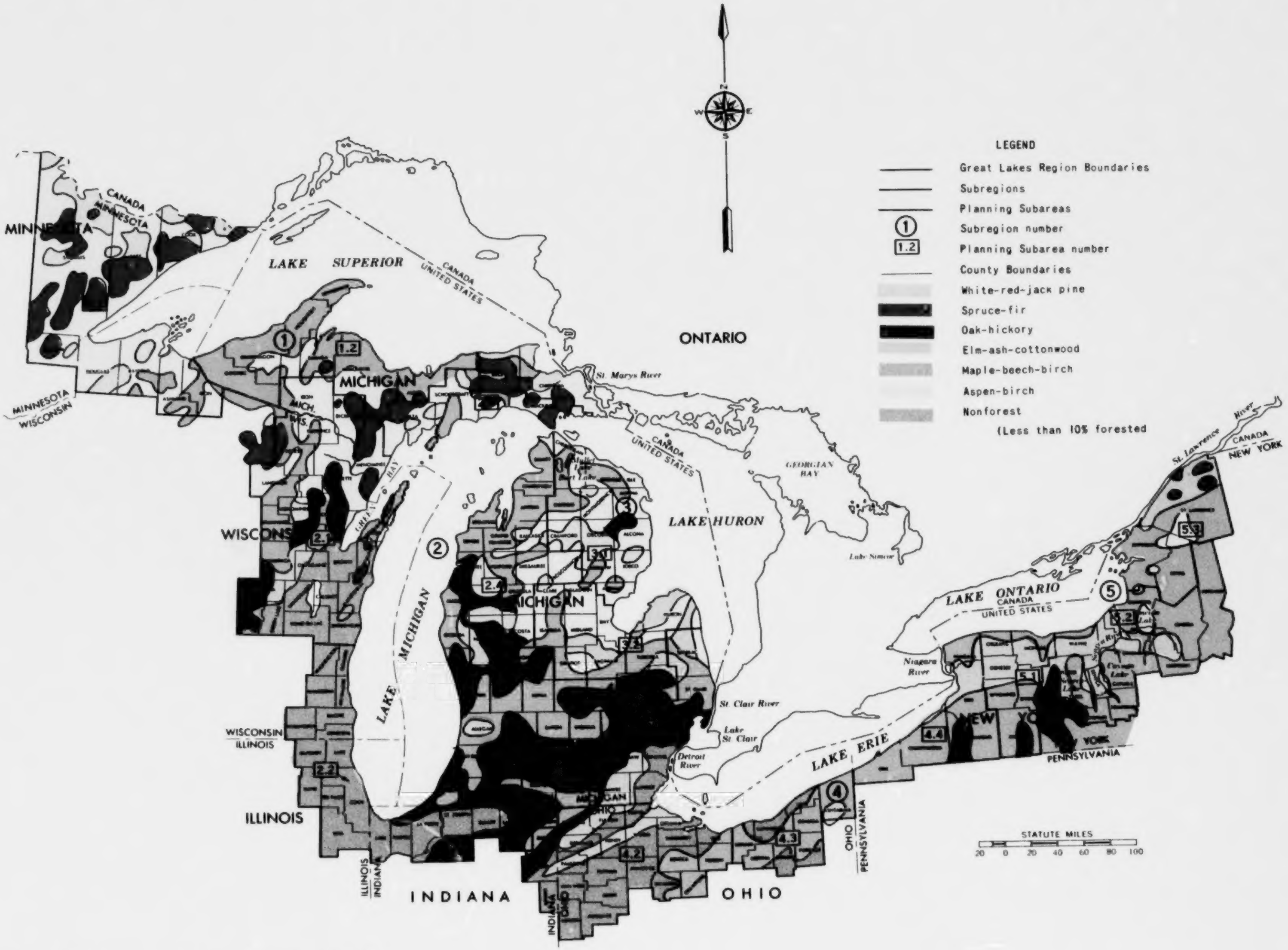

LEGEND
Great Lakes Region Boundaries
Subregions
Planning Subareas
① Subregion number
1.2 Planning Subarea number
County Boundaries
White-red-jack pine
Spruce-fir
Oak-hickory
Elm-ash-cottonwood
Maple-beech-birch
Aspen-birch
Nonforest
(Less than 10% forested
N
S
E
W
STATUTE MILES
20 0 20 40 60 80 100
ONTARIO
MINNESOTA
CANADA
MINNESOTA
MINNESOTA
WISCONSIN
LAKE SUPERIOR
CANADA
UNITED STATES
MICHIGAN
MICH.
WIS.
St. Marys River
CANADA
UNITED STATES
GEORGIAN BAY
Lake Simcoe
LAKE HURON
WISCONSIN
GREEN BAY
LAKE MICHIGAN
MICHIGAN
WISCONSIN
ILLINOIS
ILLINOIS
ILLINOIS
INDIANA
INDIANA
INDIANA
OHIO
MICHIGAN
OHIO
OHIO
PENNSYLVANIA
St. Clair River
Lake St. Clair
Detroit River
LAKE ERIE
Niagara River
LAKE ONTARIO
CANADA
UNITED STATES
NEW YORK
PENNSYLVANIA
St. Lawrence River
CANADA
NEW YORK
① ② ③ ④ ⑤
1.2
2.1
2.2
2.4
3.1
3.2
4.2
4.3
4.4
5.1
5.2
5.3

FIGURE 13 Major Forest Types[9]

furbearers. There are about 63 species of mammals and 300 species of birds native to the Basin. Game birds include the pheasant, ruffed grouse, geese, and ducks.

Fish habitat provided by inland streams and lakes, as well as the Great Lakes, supports a wide variety of cold- and warmwater species for sport fishing and a limited commercial fishery. Habitat conditions vary over inland lakes and streams with coldwater species dominating in the northern half of the Basin and warmwater species most common in the southern portion.

About 173 species in 75 genera and 29 families are represented in the Great Lakes system. In addition to those which found their way to the Great Lakes by natural means are 11 species which have been purposely or accidentally introduced and have established themselves. An additional 7 species were introduced but failed to establish permanent populations.[10]

Polychlorinated biphenyls (PCBs), which are toxic to a wide range of animals, including humans, have been found at above-tolerance levels in large lake trout and salmon in the Great Lakes. The effect of high PCB levels on fish populations is a source of concern.

DEMOGRAPHIC AND ECONOMIC CHARACTERISTICS

Population

The availability and high quality of natural resources were major determinants in early settlement of the Basin, and they continue to be major factors in development patterns. Consequently, a majority of the people in the Basin are concentrated in port and industrial centers along the shores of the Great Lakes or near the junctions of major land and water transportation routes. In addition to this rapid growth of urbanized centers, some rural nonfarm areas continue to grow rapidly.

Although the Great Lakes Region is only about four percent of the nation's area, the population has consistently accounted for about 15 percent of the people in the United States in the census decades from 1940 to 1970 (in 1970, 14.4 percent). The population density for the Region is four times the national average. There is considerable variation among Lake basins in population distribution and in urban-rural balance. The Lake Michigan and Erie Plan Areas have accounted for about 46 and 39 percent respectively of the total population of the Region in the period 1940 to 1970. Nine percent of the Region's total population is in the Lake Ontario Plan Area, four percent in the Lake Huron Plan Area, and two percent in the Lake Superior Plan Area.

Major urban complexes accounting for a dominant share of the Region's population include Milwaukee, Wisconsin; Chicago, Illinois; Detroit, Michigan; Cleveland, Ohio; and Buffalo, New York. Over 80 percent of the population is classified as urban.

The northern and inland portions of the Basin are more sparsely populated than areas situated along or near the Great Lakes shoreline (Figure 14). Population densities are lowest in northern Minnesota, Wisconsin, Michigan, and

TABLE 5 Population Distribution, Great Lakes Region[1]

Plan Area	Number of Persons		Population Distribution		
	1960	1970	Percent of PSA	Percent of Plan Area	Percent of GL Region
1.0	544,784	533,539	---	100	1.8
1.1	358,722	345,155	100	68.1	1.2
MI	---	---	---	---	---
MN	276,599	265,539	77	---	---
WI	82,123	79,616	23	---	---
1.2	186,062	188,384	100	38.2	0.6
MI	186,062	188,384	100	---	---
WI	---	---	---	---	---
2.0	12,041,378	13,516,992	---	100	46.1
2.1	896,396	1,005,065	100	7.4	3.4
MI	65,786	62,153	6	---	---
WI	830,610	942,912	94	---	---
2.2	8,481,097	9,491,743	100	70.2	32.4
IL	6,220,913	6,977,671	74	---	---
IN	686,570	757,989	8	---	---
MI	---	---	---	---	---
WI	1,573,614	1,756,083	18	---	---
2.3	2,211,001	2,522,644	100	18.7	8.6
IN	440,573	478,991	19	---	---
MI	1,770,428	2,043,653	81	---	---
2.4	452,884	496,540	100	3.7	1.7
MI	452,884	496,540	100	---	---
3.0	1,056,577	1,237,557	---	100	4.2
3.1	119,007	142,064	100	11.5	0.5
MI	119,007	142,064	100	---	---
3.2	937,570	1,095,493	100	88.5	3.7
MI	937,570	1,095,493	100	---	---
4.0	10,465,813	11,217,849	---	100	39.3
4.1	4,291,457	4,853,097	100	42.1	16.5
MI	4,291,457	4,853,097	100	---	---
OH	---	---	---	---	---
4.2	1,565,736	1,724,868	100	15.0	5.9
IN	285,110	338,163	20	---	---
MI	---	---	---	---	---
OH	1,280,626	1,386,705	80	---	---
4.3	2,825,417	3,098,048	100	26.9	10.6
OH	2,825,417	3,098,048	100	---	---
PA	---	---	---	---	---
4.4	1,783,203	1,841,836	100	16.0	6.3
NY	1,532,521	1,578,182	86	---	---
PA	250,682	263,654	14	---	---
5.0	2,256,046	2,531,947	---	100	8.6
5.1	797,364	946,131	100	37.4	3.2
NY	797,364	946,131	100	---	---
PA	---	---	---	---	---
5.2	1,236,359	1,361,673	100	53.8	4.6
NY	1,236,359	1,361,673	100	---	---
5.3	222,323	224,143	100	8.8	0.8
NY	222,323	224,143	100	---	---
GL TOTAL	23,364,598	29,037,884	---	---	---

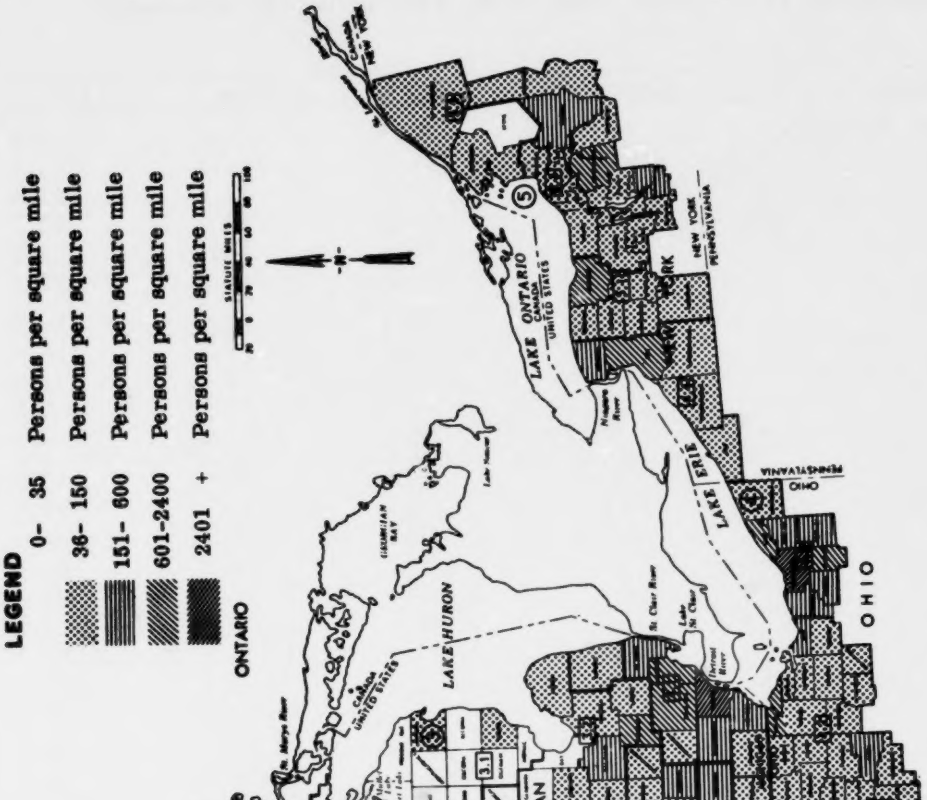

LEGEND
0- 35 Persons per square mile
36- 150 Persons per square mile
151- 600 Persons per square mile
601-2400 Persons per square mile
2401 + Persons per square mile
ONTARIO
STATUTE MILES
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
GEORGIAN BAY
St. Marys River
St. Clair River
Lake St. Clair
Detroit River
Niagara River
CANADA
UNITED STATES
MINNESOTA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
NEW YORK
PENNSYLVANIA
1
2
3
4
5
1.2
2.1
2.4
3.1

FIGURE 14 Population per Square Mile for Great Lakes Region Counties 1970[5]

TABLE 6 Employment by Selected Industries, 1950-1970[1] (in thousands)

Industry	Plan Area	1950	1960	1970
Agriculture, Forestry, Fisheries	1.0	18.3	7.6	3.8
	2.0	220.0	142.2	95.1
	3.0	40.6	21.3	11.4
	4.0	131.8	87.2	58.7
	5.0	69.0	47.3	31.7
Total		479.7	305.8	200.7
Mining	1.0	19.3	21.9	17.0
	2.0	7.2	7.3	8.4
	3.0	2.3	2.0	1.7
	4.0	5.8	5.7	8.7
	5.0	3.8	3.6	3.2
Total		38.7	40.5	39.0
Manufacturing	1.0	33.4	27.7	25.5
	2.0	1,544.6	1,769.1	1,808.4
	3.0	120.3	146.6	165.4
	4.0	1,422.6	1,532.5	1,597.4
	5.0	264.2	295.2	308.8
Total		3,385.1	3,771.0	3,905.5
Other (includes Federal Military)	1.0	109.2	117.3	125.5
	2.0	2,339.8	2,756.9	3,436.0
	3.0	137.9	186.1	243.5
	4.0	1,808.4	2,175.9	2,731.3
	5.0	407.2	488.2	620.7
Total		4,802.5	5,724.6	7,157.1
Total Employment	1.0	180.2	174.5	171.8
	2.0	4,111.6	4,675.4	5,347.9
	3.0	301.5	356.0	422.1
	4.0	3,368.6	3.801.4	4,396.2
	5.0	744.1	834.6	964.4
Total		8,706.0	9,841.8	11,302.3

Note: Entries may not add to total because of rounding.

New York. Declines in population have been noted in some counties in these areas (Table 5).

Resource Use and Development

The Great Lakes Region is typified by a wide variety of economic conditions and occupational pursuits. The northern Basin is characterized by industry dependent upon forest and mineral resources and heavy reliance upon the growth of year-round recreation. Low family incomes, out-migration, and poor farming are typical in many of these areas. Agriculture and diversified manufacturing are concentrated in the central section of the Basin, while on the lakeshores are a number of centers for heavy industry with emphasis on iron, steel, petroleum and chemical production. General farming is practiced over large areas in the southern part of the Basin, while specialized crops are grown along the lee sides of the Lakes. The recreation industry is important in the northern and eastern sections of the Basin.

About 50 percent of the nation's steel production comes from the Great Lakes Region. Nearly 8 percent of the nation's mineral production value came from the Region in 1968. Slightly over 71 percent of the nation's iron ore dollar value was derived from the Great Lakes area in that year.

In 1970 approximately 11.3 million persons (38.5 percent of the population) found employment in agriculture, forestry, fisheries, mining, manufacturing, trades and services, and other occupations in the Region (Table 6).

Nearly $114 billion in total personal income (18 percent of the national total) was generated in the Region in 1970. The heavy concentration of industrial activity has supported per capita income and personal income at a level 20 percent higher than for the country as a whole.

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MAJOR LAND USES(1)

INTRODUCTION

In 1972 the governments of Canada and the United States upon signing the Great Lakes Water Quality Agreement requested that the International Joint Commission (IJC) investigate pollution of the boundary waters of the Great Lakes system from agriculture, forestry and other land use activities. In 1973 the IJC charged its Reference Group on Great Lakes Pollution from Land Use Activities with the responsibility of obtaining a land use inventory of the Great Lakes Basin. The results of this inventory will be used to determine the contribution to the pollution of the Great Lakes from land use activities.

In the summer of 1973 representatives of the Reference Group, Environmental Protection Agency, U.S. Department of Agriculture/Soil Conservation Service, and the Laboratory for Applications of Remote Sensing (LARS)/Purdue University met to discuss the feasibility of using computer-aided analysis of LANDSAT-1 (formerly known as the Earth Resources Technology Satellite) data to produce a land use inventory. Funds were made available from the Office of University Affairs/National Aeronautics and Space Administration to conduct a pilot study. LANDSAT multispectral scanner (MSS) data covering a 6-county area in southwestern Michigan were analyzed with the use of LARSYS, a digital computer software system developed at LARS. With the aid of limited reference data, a satisfactory land use inventory was prepared for this area.

This successful study led the Environmental Protection Agency to contract with Purdue University/LARS to prepare for the Reference Group a current land use inventory of the 34,000,000 hectares (84,000,000 acres) included within the U.S. portion of the Great Lakes Basin.

The U.S. portion of the Great Lakes Basin covers an area approximately 1450 x 1000 km (900 x 620 miles) in the east/west and north/south directions, respectively. The Basin includes Michigan and portions of seven other states and contains 191 counties. Land use within the Basin varies from mixed hardwood and coniferous forests, lakes, and wetlands in the northern portion to complex agricultural land uses in the south. In addition, there are several large metropolitan areas which include varying degrees of residential, commercial and industrial land uses.

Approach

LANDSAT multispectral scanner data, collected from the 1972 and 1973 growing seasons were used as the prime data source for analysis. In addition, 70mm color and color infrared aerial photography was used as underflight reference data. The underflight data were collected over flight lines which represented the land use classes throughout the watershed.

These LANDSAT MSS data were analyzed by computer-implemented pattern recognition techniques to produce spectrally separable classes which were then related to the land use categories listed in Table 7.

Table 7

LAND USE CATEGORIES CLASSIFIED

Level I	Level II
Urban	Residential Commercial/Industrial
Agriculture	Row Crops Close Grown Crops Pasture and Meadows
Forest	Forest
No Major Usage[1/]	Water Wetlands

[1/] The residual inland area not devoted to urban, agricultural or forest use.

Results

Results of the land use inventory are reported in two forms: geometrically correct color-coded maps and statistical tables. Individual geometrically correct county maps were produced with each of the Level I land use categories represented by a designated color. Statistical tables of each county were compiled which include both primary and secondary levels of land use with each category reported as 1) percentage of the county area, 2) the number of hectares and 3) the number of acres present in each county.

LAND USE INVENTORY PROCEDURES

The results of any land use inventory are highly dependent upon the data from which the information is derived. In a project such as this Great Lakes Land Use Inventory, where computer-aided analysis of single-pass satellite data is the primary source of information, the following would be the optimal conditions for data collection:

(1) Cloud-free, satellite data, sufficient to cover the watershed, would be collected on consecutive satellite passes.

(2) Underflight reference data and ground observations would be collected concurrent with the satellite overpass. The quantity of ground truth collected would be adequate to characterize all desired land use categories.

(3) Data would be collected at the time of year during which the maximum number of desired land use classes are spectrally separable.

In the Great Lakes Land Use Inventory, LANDSAT multispectral scanner data were utilized as the primary data source. To allow for the identification of the maximum number of desired land use classes, multispectral data were used only from LANDSAT passes between April and October of 1972 or 1973. In order to be able to obtain cloud-free data over the entire watershed, it was necessary to select data from the growing seasons of both years. LANDSAT data were selected by LARS personnel applying the following criteria:

(1) The scene must be as free of cloud cover as possible.

(2) All spectral bands must be of good quality.

(3) The scene should be from the most recent year available meeting criteria 1 and 2.

In the selection process a listing of the best available LANDSAT data for the Great Lakes Basin was produced. The USDA/SCS used this list for purchasing the data from the EROS Data Center.

In addition to LANDSAT data, aerial photography was collected for use as underflight reference data. This consisted of 70mm color and color infrared photography, taken at approximately 3,000 meters (9600 feet) altitude during August 1973 and June 1974. Coverage by aerial photography represents approximately 4 percent of the total area of the Great Lakes Basin. Flight lines were chosen which represented the majority of the land use classes found throughout the plan areas. It should be observed that the underflight reference data were not collected concurrent with any satellite overpass.

Other reference data include:

(1) County highway maps

(2) 1:24,000 United States Geological Survey topographic maps

(3) 1:250,000 United States Geological Survey topographic maps

(4) County soil surveys

(5) City maps

(6) 1967 Conservation Needs Inventory (USDA/SCS)

(7) 1972, 1973 reports of the Statistical Reporting Service (USDA).

Processing and Analysis

Since the results of this project were to be presented at the county level, this dictated that several rather small analysis tasks be performed as opposed to a few tasks covering large areas. In order to standardize the analysis procedures, a comprehensive procedures document was prepared. This document was concerned with the areas of data preprocessing, analysis and results and is summarized in the following paragraphs.

Data Preprocessing

Upon receipt from the EROS Data Center, LANDSAT MSS data were cataloged into the LARS data library and forwarded to the LARS computer facility to be reformatted into a form compatible with the LARS computer software system. Individual county data sets were then prepared. This was accomplished by first locating the county within the appropriate frame of LANDSAT data and requesting that a portion of the data containing the desired county be geometrically corrected. The geometric correction procedure accomplished the following:

(1) rotated the data to a north-south orientation,

(2) eliminated skew within the data caused by earth's rotation, and

(3) rescaled the data (1:1 aspect ratio).

Next, the geometrically corrected areas were displayed upon a digital image display unit and the individual county boundary was delineated with the use of a light pen to input line and column coordinates to approximate the boundary by a series of straight lines. The boundaries were selected by comparing visible features contained within the data (streams, lakes, roads, cities, etc.) to information contained on topographic and county highway maps. The county boundaries generated were generally within ± 400 meters (1/4 mile) of the actual county boundary.

After the individual counties were outlined, the *GENTAPE processor, developed during this project, was used to generate separate data sets containing only the data within the county boundaries. These data sets were used by the analysts for classification of the county.

For some counties, no single LANDSAT frame existed which contained the entire county. For those counties which overlapped two frames of data taken on the same day, where one frame was south of the other, the overlapping lines of the two frames could be removed and the desired data connected into one data set. From these data the area to be geometrically corrected was then selected and the county boundaries delineated as previously described. If the county overlapped two frames in an east-west manner or was contained in two north-south frames of different dates, two separate data sets for the county had to be generated since the data were collected under different atmospheric conditions and different calibration parameters. If this were the case, the county was treated as two individual data sets during the analysis procedure.

Analysis

Prior to analysis the 191 counties were divided into two categories: (a) those having underflight reference data available and (b) those having no underflight reference data. Those counties which had sufficient underflight data were analyzed and classified from statistics generated within the county. The statistics were prepared utilizing the underflight data and other available reference data to obtain informational classes from the spectral classes. Counties which did not have underflight data were classified using the statistics generated from an adjoining or nearest neighbor county. This procedure assumed that training statistics generated in one county could be extended over a distance of 90 to 100 kilometers (50-60 miles). However, it was stipulated that the statistics could not be extended to areas outside the frame of LANDSAT data from which they were generated.

Analysis Procedure

Computer-implemented pattern recognition techniques, LARSYS Version 3, were utilized to classify the LANDSAT data into spectrally separable classes which could be related to informational land use categories. Details of the analysis procedures are given in nine steps:

1) A grey-scale representation of the spectral bands 5 and 7 for each data set (county) was obtained by using the *PICTUREPRINT processor. This processor divides the radiance values of each spectral band into 16 equal groupings of grey-level values. The output of this processor is a computer printout with each grey-level grouping represented by an individual alphanumeric symbol. The location of the flight line for the appropriate underflight reference data was marked on the computer printout. By comparison of the grey-scale information and the underflight reference data

it was possible for the analyst to observe gross relationships between land use categories and spectral data.

2) From observation of the grey-scale/flight line information the analyst selected the line and column coordinates of areas of interest for input into the modified *CLUSTER processor. This processor utilizes data from all spectral bands to cluster the spectral data into classes containing similar spectral characteristics. This processor also provides statistical information on the homogeneity and separability of the cluster classes. These classes were identified by relating them to the underflight reference data to obtain informational subclasses. Utilizing the statistical information provided, the analyst retained, combined or deleted the informational subclasses on the basis of their spectral separability.

3) The *MERGESTATISTICS processor was used to develop informational subclasses from different clustering tasks. These subclasses were retained, combined, or deleted according to the separability information provided in the cluster processor and also by comparison of the relationship of subclasses to available underflight reference data.

4) The new statistics deck generated from *MERGESTATISTICS processor was input into the *SEPARABILITY processor and the separability of subclasses once again verified.

5) Using the statistics deck obtained above, the area defined as the county was classified using a weighted version of the *CLASSIFYPOINTS algorithm (based on the maximum likelihood probability function). Data obtained from the 1967 Conservation Needs Inventory was input as "a priori" information for the various class weights. In order to conserve computer time during classification only bands 5, 6 and 7 of the LANDSAT data were utilized. Studies indicated that no significant differences resulted between a 3-band land use classification versus a 4-band classification. Each county was classified from only every other line and column of data, with each data point representing approximately 2.4 hectares (6 acres).

6) After classification the *PRINTRESULTS processor produced an alphanumeric printout of the Level I land use categories and the Level I and Level II tabular land use statistics for each county. Tabular information was obtained by inputting the area of the county into the *PRINTRESULTS processor, modified for this project, and allowing the computer to determine the area represented by each individual point classified. The area was computed for each land use category yielding tables which listed the acreage, hectares, and percentage of county area in each class to the nearest four hectares (10 acres).

The classification printouts and tabular information were compared to the 1967 Conservation Needs Inventory, 1972, 1973 USDA

Statistical Reporting Service Reports and other available data and a determination was made as to the validity of the classification.

7) If the classification was accepted as the final version, the results (classification tape) and the statistics deck used in the classification were archived. If the classification was rejected, steps 2-6 were repeated.

8) After the counties with underflight reference data were classified and accepted, the appropriate statistics deck was used to classify the appropriate county where no underflight reference data existed.

9) Step 6 of the procedure was then followed and the results archived.

Pilot Study

During the initial phase of the project a pilot study was conducted to determine if the proposed land use categories could be routinely identified, to test the proposed analysis techniques, and to evaluate the performance of the proposed classification scheme. Table 8 lists the fifteen counties chosen for the pilot study. The pilot counties were selected to represent diverse land use categories and mixtures of categories distributed throughout the watershed. During the planning of the pilot study, it was proposed that each county be classified utilizing all the data points to allow for maximum resolution. Thus, each point classified represented approximately 0.6 hectares (1.5 acres).

In each county a block of approximately 64 hectares (1/4 section) was randomly selected from each township. These areas were to be used to check the performance of the classification scheme. As an example Figure 15 illustrates the 1/4 sections selected for Green Lake County, Wisconsin. A map of each county marked with the appropriately selected 1/4 sections was sent to United States Department of Agriculture/Soil Conservation Service representatives in the respective counties for a field survey of the designated areas. This map was accompanied by the reporting form shown in Figure 16, an instruction sheet (Figure 17), and a definition of classes (Table 9).

While the field data were being collected, the pilot counties were independently classified at the LARS facility. After classification, the 1/4 sections were located on a classification printout of each county. Difficulty was encountered in precisely locating the 1/4 sections on the printouts since distinguishing landmarks could not be easily located within the classification. In this study the evaluation of classification performance was greatly dependent upon the analysts' ability to locate precisely the ground observation points (an array of points 10 lines x 10 columns) on the classification output. If location of the 1/4 section was off by only one line or one column, an error of 10% was immediately introduced. If it

Table 8

COUNTIES INCLUDED IN PILOT STUDY

State	County
Indiana	Elkhart
	LaGrange
Michigan	Cass
	Lake
	Luce
	Newaygo
	Ottawa
	St. Joseph
	Wexford
Wisconsin	Green Lake
	Outagamie
	Winnebago
New York	Cayuga
	Oswego
	Wayne

were off by one line and one column, there would be an error of 20%. It was decided that individual 1/4 sections could not be located with sufficient precision and, thus, not properly evaluated. However, it was decided to aggregate the field information and evaluate the classification performance on a county basis.

Because of the late spring thaw and other delays the field results for some of the fifteen pilot counties were not received in time to allow a complete evaluation of the classification results. Some classification results were spot checked in the field by officials in a few counties. They reported that the results seemed reasonable.

An analysis of variance was performed for those counties for which field data were received. Results indicated that in those counties where training sets were selected there was no significant difference (95% confidence level) between the land use classification by computer-aided analysis of satellite data and the land use classification by field observation.

For counties which were classified with spectral training sets selected from adjacent counties there were some land use classes where a significant

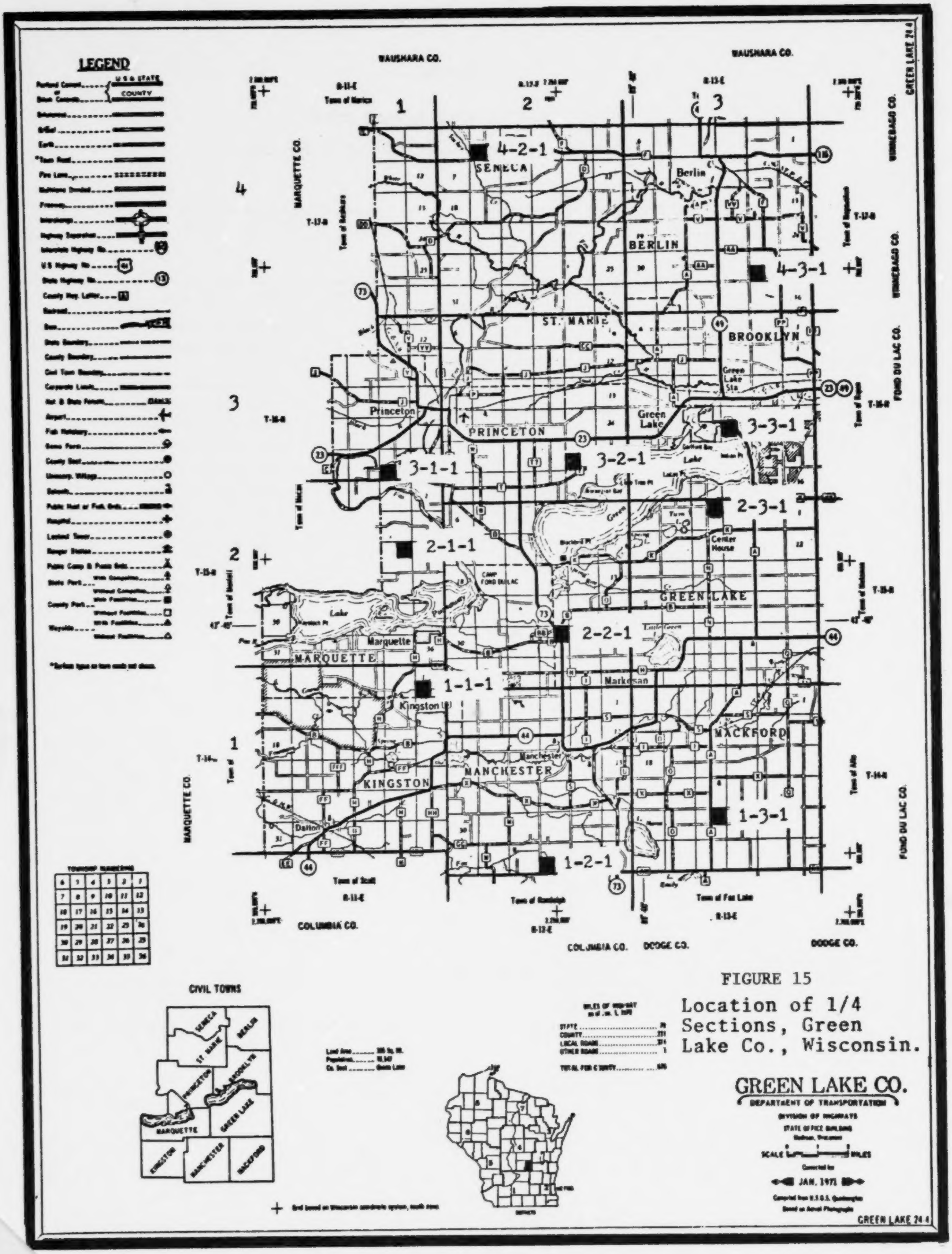
LEGEND
WAUSHARA CO.
WAUSHARA CO.
MARQUETTE CO.
WINNEBAGO CO.
FOND DU LAC CO.
COLUMBIA CO.
DODGE CO.
1
2
3
4
3
2
1
4-2-1
4-3-1
3-1-1
3-2-1
3-3-1
2-1-1
2-2-1
2-3-1
1-1-1
1-2-1
1-3-1
SENECA
BERLIN
Berlin
ST. MARIE
BROOKLYN
PRINCETON
Princeton
Green Lake
GREEN LAKE
MARQUETTE
Marquette
Markesan
Kingston
KINGSTON
MANCHESTER
MACKFORD
Dalton
TOWNSHIP NUMBERING
CIVIL TOWNS
GREEN LAKE CO.
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
STATE OFFICE BUILDING
Madison, Wisconsin
SCALE
MILES
JAN. 1971
GREEN LAKE 24-4

FIGURE 15

Location of 1/4 Sections, Green Lake Co., Wisconsin.

FIGURE 16

SAMPLE AREA REPORT FORM

Great Lakes Land Use Inventory Project

County ____________________ State ____________________

Sample ____________________ 1/4 sec. - Twp. - Range ____________________

CLASSES — ESTIMATED ACREAGE (197_ Growing Season)

1. RESIDENTIAL ____________
2. COMMERCIAL ____________
3. TRANSPORTATION (Only dual lane hwys) ____________
4. EXTRACTIVE (Gravel pits and quarries) ____________
5. ROW CROPS ____________
6. CLOSE GROWN CROPS ____________
7. PASTURE AND MEADOWS ____________
8. ORCHARDS AND VINEYARDS ____________
9. FOREST ____________
10. WATER ____________
11. WETLANDS ____________
12. BARREN LANDS (Sand dunes, bare rock) ____________
13. OTHER ____________________________ ____________

____

TOTAL ACREAGE (Should be 160)

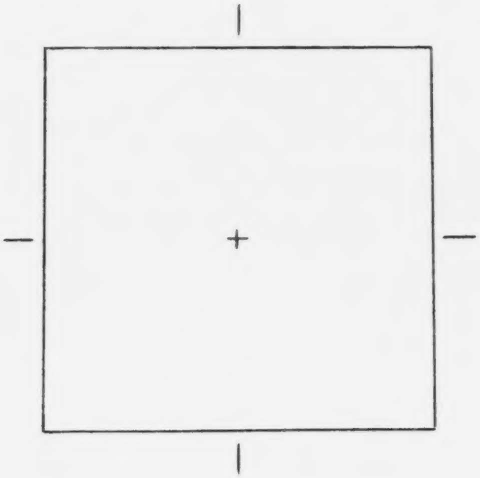

FIGURE 17

SAMPLE AREA REPORT FORM INSTRUCTIONS

Great Lakes Land Use Inventory Project

The Laboratory for Applications of Remote Sensing (LARS) at Purdue University is currently preparing a land use inventory of each of the nearly 200 counties in the Great Lakes Watershed. This information is being gathered persuant to the Great Lakes Water Quality Agreement of 1972 signed by the United States and Canada.

In order to complete this job in a relatively short period of time, we are using data from the Earth Resource Technology Satellite (ERTS-1) and analyzing it with a computer.

We have selected 15 counties in the watershed on which to test the accuracy of our results. Your county has just been selected to help us with this task.

The procedure is somewhat similar to the Conservation Needs Inventory in which you may have participated a few years ago. There are about 15 sample areas of 160 acres each that have been randomly selected throughout your county. The accompanying map shows the location and number designation of each of these samples. We need to know the number of acres of each land use (as it was during the 197_ growing season) that is within each sample area. The land use acreage should be entered on the appropriate line of the Sample Area Report Form under the heading of estimated acreage. We would also like a rough sketch of each class in the large square at the bottom of the form. A sample form and class definitions are included for your guide. Please use the conventional conservation planning symbols as necessary for clarity.

It is entirely possible that you may have an area of land use for which there is no appropriate class on the Sample Area Report Form. Should you have such an area, please estimate the acreage and briefly describe it on the last line of the form (line 13).

When you have measured all the sample areas and filled out all the Sample Area Report Forms, please return them to LARS. We would like to have all the information returned to us by March 29, 1974.

TABLE 9

CLASS DEFINITIONS

Residential - any area of 3 or more dwellings/acre on at least 3 acres or a minimum of 9 dwellings in each 3 acre tract. However, strip developments along highways that do not meet these minimum requirements should still be classified as residential.

Commercial - any area where large buildings are relatively closely spaced. Also include attendant parking areas or other hard surfaces, stone driveways, roads, etc. in the commercial class. Area should be 3 acres or more in size. Please indicate the kind of surface material on large parking lots - such as asphalt, crushed stone, gravel, etc.

Transportation - show location of dual lane highways only.

Extractive - any area of extractive activity (active or abandoned) that is 3 acres or larger. Such areas as gravel pits, sand pits, clay pits, rock quarries and borrow pits are examples of this class.

Row Crops - any area of cropland that has cultivated rows of plants such as corn, soybeans, grain sorghum, etc.

Close Grown Crops - any area of cropland in which the plants are grown in such a way that it is impossible to mechanically cultivate between rows. Such crops are oats, wheat, rye, barley, etc.

Pasture and Meadow - any area of more or less perennial grassland includes permanent pasture, hayland and areas of green manure crops.

Orchards and Vineyards - any area of which the primary use is orchard or vineyards.

Forest - any area which has at least 40 percent crown cover. This class includes area of brush that meets the 40 percent crown cover requirement. It is not necessary that there be merchantable timber to call it forest. Wooded grazing land that meets the 40 percent crown cover should be classed as forest.

Water - any area of open water such as lakes, ponds, water filled pits, creeks, rivers, ditches, canals, etc.

Wetlands - any area of water that has vegetation over 90 percent of the surface area. Wetlands may dry up during extended dry spells but generally they are wet enough that they cannot be farmed. Swamps and marshes are examples of this class.

Barren Lands - any area of sand dunes or bare rock that has only sparse or no vegetation growing on it.

Other - any area of 3 acres or more that does not fit into one of the above classes. Please briefly describe this class on the sample Area Report Form, i. e., parks, golf courses, etc.

difference (95% confidence level) existed between the spectral classification and the classification by field observation. However, this difference was not considered sufficient to render the classification results unacceptable.

Classification difficulties occurred because of spectral similarities between (1) residential and forest, (2) residential and pasture/meadow, (3) commercial/industrial and light colored bare soils. These difficulties existed in all data sets, and no successful method employing single date data was developed to provide satisfactory separability. Spectral separability between these classes can be improved by using appropriate multiple-date, multi-band data sets; however, this technique was not within the scope of this project.

In addition to these problems, minor difficulties occurred in areas covered by light scattered clouds. Thin cirrus clouds often were classified as urban (commercial/industrial) regardless of the ground cover because the cloud cover was the dominating feature. Likewise cloud shadows sometimes were classified as water. However, the occurrence of these difficulties was limited.

A study was also conducted to determine if training statistics generated on one county could be extended into an adjoining county or nearest neighbor county. The results of this effort indicated that the classification performance tended to decrease slightly as the training statistics were applied to areas other than where they were generated. However, this decrease was generally not more than 5-10% if the extension of the statistics was limited to 90 to 100 kilometers (50-60 miles). The decrease occurred regardless of the direction of extension but appeared to be more pronounced in the N-S than E-W direction. No definite explanation of the decrease in performance can be given except for the fact that much of the LANDSAT data were collected in early June and climatic effects may have been affecting the relative responses in many areas. Also, undoubtedly, the Great Lakes were influencing the climate and thus the vegetative characteristics of the area.

Since the LARS land use statistics of the pilot counties were judged to be acceptable, it was concluded that the analysis procedures were adequate to produce the desired results. The results of the pilot study also indicate that all of the land use categories listed in Table 10 were not spectrally separable in the majority of the data and some of the categories could not be routinely identified because of insufficient underflight reference data. Table 11 lists the categories which could be routinely identified and inventoried taking into consideration the variability in dates of data collection and the limited amount of underflight reference data available.

TABLE 10

PROPOSED LAND USE CLASSIFICATION CATEGORIES

Level I	Level II	Level III
1. Urban-Commercial-Industrial		
	a. Residential	(1) Man-made hard surfaces less than 10% of area (low density)
		(2) Man-made hard surfaces 10-25% of area (medium density)
		(3) Man-made hard surfaces over 25% of area (high density)
	b. Commercial and Industrial	(1) Man-made hard surfaces less than 10% of area (low density)
		(2) Man-made hard surfaces 10-25% of area (medium density)
		(3) Man-made hard surfaces over 25% of area (high density)
	c. Transportation	
	d. Extractive	
2. Agriculture		
	a. Row crops	
	b. Close grown crops	
	c. Pastures and meadows	
	d. Orchards and vineyards	
3. Forest		
4. No Major Use[1]		
	a. Water	
	b. Wetland	
	c. Barren land	

---

[1] The residual inland area not devoted to urban, agricultural or forest use.

TABLE 11

FINAL LAND USE CLASSIFICATION CATEGORIES

Level I	Level II
Urban	
	Residential
	Commercial/Industrial
Agricultural	
	Row Crops
	Close Grown Crops
	Pasture
Forest	
	Forest
No Major Use[1/]	
	Water
	Wetland

[1/] The residual inland area not devoted to urban, agricultural or forest use.

Classification Variations

Throughout the project the urban land use category was generally classified into two Level II classes, i.e., residential and commercial/industrial. Level II transportation and extractive classes as well as the Level III residential and commercial/industrial classes were not included in the inventory because they could not be routinely identified due to insufficient underflight reference data. However, this is not to imply that transportation routes, extractive areas, and a division of residential and commercial/industrial areas cannot be identified. With sufficient and appropriate reference data these categories can be readily identified.

In some counties only the Level I urban category was classified with no distinction being made between the residential and commercial/industrial categories. The Level II results of these counties are reported only as residential. In a few predominantly rural counties insufficient underflight reference data were available to train properly the computer to identify any urban class. In these instances only the remaining classes of agriculture, forestry and no major use were classified. However, the tabulation of statistics includes an urban/residential category.

The urban statistics used in these tables were taken from the appropriate 1967 Conservation Needs Inventory. The areas included in these artificial classes were subtracted from the forest area of the respective counties. This is justifiable since most small towns are spectrally similar to forest areas. The maps of these counties do not include an urban category.

The agriculture category was generally classified into two Level II classes, i.e., bare soil and pasture/meadow/close grown crops. A procedure was developed which allowed the analysts to relate the areas classified as bare soil to row crops planted. This procedure was based on a study conducted in 1974 on data from Boone County, located in central Indiana. In this study the amount of bare soil in Boone County was inventoried using June 1973 LANDSAT data. That area classified as bare soil was used as an estimate of the area of row crop that would be planted that year. This figure was compared to the area of row crop grown in Boone County in 1973 as determined by the United States Department of Agriculture/Statistical Reporting Service (USDA/SRS). The LARS estimated figure was comparable to the USDA/SRS figure, yielding an estimate approximately 2% greater than that reported by SRS. Thus, since the majority of the LANDSAT data were collected in June of 1972 and 1973, bare soil was used as an indicator of row crops. Areas covered by LANDSAT data collected later in the growing season allowed for direct classification of row crops.

Generally with all the LANDSAT data, pasture/meadow was not spectrally separable from close grown crops. In this situation a pasture/meadow/close grown crops category was classified. These classes were artificially separated into the pasture/meadow and close grown crops classes. This artificial separation of classes was performed by subtracting the area of close grown crops (wheat, oats, and barley) as reported by the USDA/SRS from the total area of pasture/meadow/close grown crops determined for each respective county for the appropriate cropping year. The remaining area was tabulated as pasture/meadow.

It was determined that orchards and vineyards were not spectrally separable in the majority of cases because sufficient underflight reference data were not available for adequate training of the computer. Thus, this class was deleted. The orchards and vineyards were included in those classes most spectrally similar, i.e., forest and pasture/meadow/close grown crops.

Forest cover was usually classified into Level II classes such as coniferous, deciduous, and sparse forest. However, these classes were aggregated to yield only a Level I forest class.

In the no major usage category only water and wetland were categorized. Insufficient underflight reference data precluded the routine classification of barren land.

RESULTS

Results of this project are represented in statistical tables which list the land use categories in Table 11 for each individual county by acreage, hectares, and percentage of county. These area statistics have been rounded off to the nearest 4-hectare (10-acre) unit. Additional tables show the aggregation of these results of state, planning subarea, and plan area totals. Some minor differences may exist in the data due to the rounding off of figures at various points of aggregation.

In addition to the tabular statistics, individual color-coded county maps have been prepared at an approximate scale of 1:215,000. These maps show the Level I categories listed in Table 11 and are color coded as shown in Table 12.

TABLE 12

COLOR CODE FOR COUNTY MAPS

Color	Level I Category
Red	Urban
Yellow	Agriculture
Green	Forest
Blue	No Major Use
Black	Cloud Shadow
White	Clouds

These maps were prepared by converting the LARS digital classification computer tapes into a format compatible with a laser digital printer located at Mead Technology Laboratory, Dayton, Ohio. With a digital laser printer Mead Technology Laboratory provided color separations of each map. These color separations were used to prepare the printing plates for the county maps.

The area included in this land use inventory is defined by the Great Lakes Region (political) boundary (Figure 18). However, at the request of the U.S./Environmental Protection Agency land use within Planning Subareas 1.1 and 2.1 was also determined for the Great Lakes Basin (hydrologic) boundary of the subareas as well as the Region boundary. This was accomplished by approximating the hydrologic boundary within each county by line and column coordinates at the *PRINTRESULTS stage and requesting that new tabular statistics be generated utilizing only the area contained within those boundaries. County maps on a hydrologic boundary basis were not prepared.

On the basis of this study, it is concluded that Great Lakes Basin land use breaks down as follows: urban, commercial, industrial 8.3 percent, agriculture 38.6 percent, forest land 47.2 percent, and water areas or wetlands 5.8 percent.

Plan Area 4 (Lake Erie) has the largest percentage of its land area in urban uses with 12.3 percent, while Planning Subarea 2.2 has the largest urban concentration of any planning subarea with 26.5 percent of its land area in urban, commercial, or industrial uses.

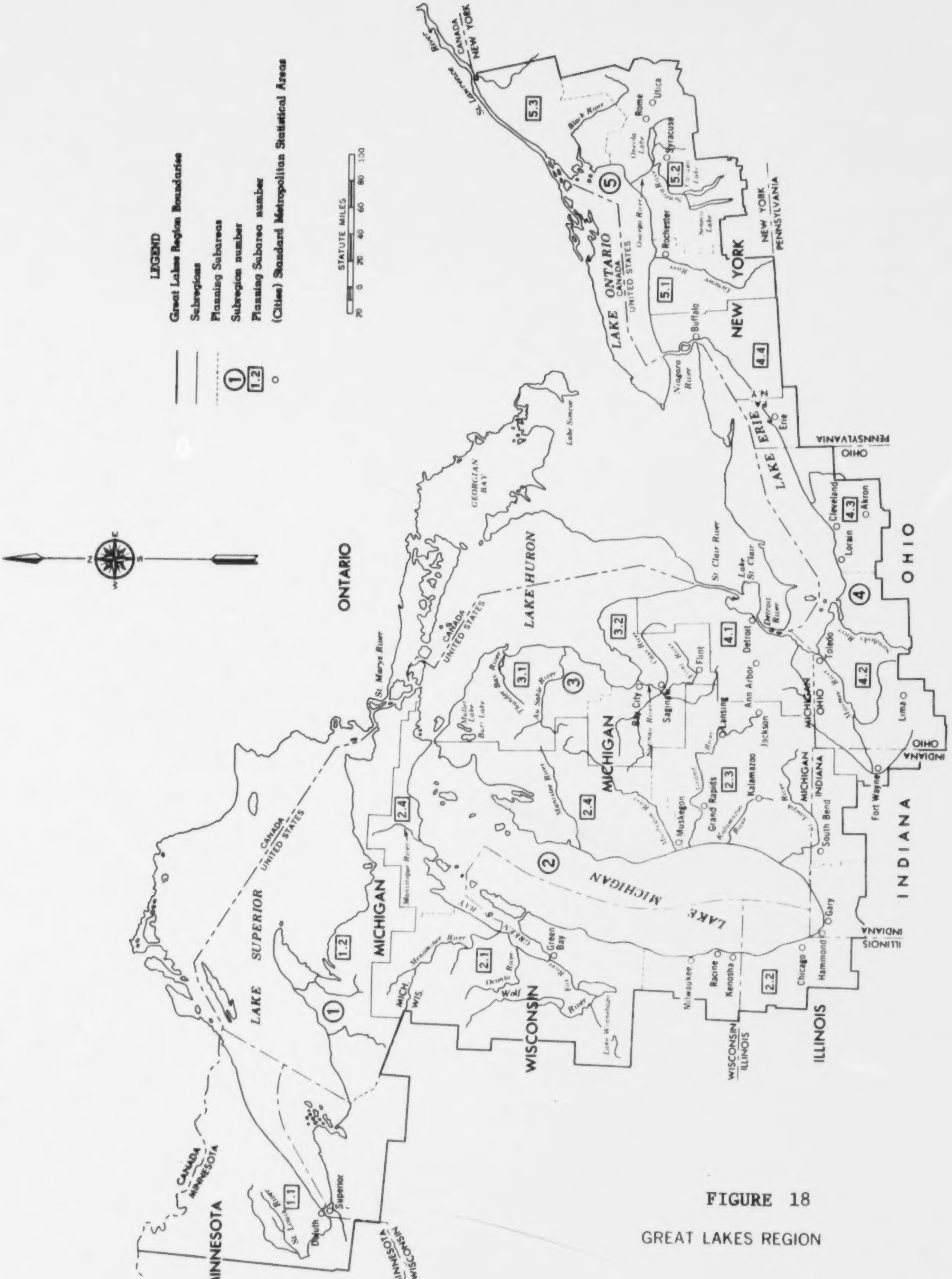
LEGEND
Great Lakes Region Boundaries
Subregions
Planning Subareas
Subregion number
Planning Subarea number
(Cities) Standard Metropolitan Statistical Areas
STATUTE MILES
20 0 20 40 60 80 100
ONTARIO
CANADA
UNITED STATES
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
GEORGIAN BAY
Lake Simcoe
MINNESOTA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW YORK
1.1
1.2
2.1
2.2
2.3
2.4
3.1
3.2
4.1
4.2
4.3
4.4
5.1
5.2
5.3
Duluth
Superior
Green Bay
Milwaukee
Racine
Kenosha
Chicago
Hammond
Gary
South Bend
Fort Wayne
Lima
Toledo
Detroit
Ann Arbor
Jackson
Lansing
Flint
Saginaw
Bay City
Muskegon
Grand Rapids
Kalamazoo
Cleveland
Lorain
Akron
Erie
Buffalo
Rochester
Syracuse
Rome
Utica
St. Marys River
St. Clair River
Lake St. Clair
Detroit River
Niagara River
Black River
St. Lawrence River
Menominee River
Fox River
Wolf
Manistee River
Au Sable River
Saginaw River
Grand River
Kalamazoo River
Maumee River
Oneida Lake
Seneca Lake
Genesee River
Oswego River

FIGURE 18

GREAT LAKES REGION

Plan Area 4 (Lake Erie) is the leading agricultural area with 62.7 percent of its total land area in agricultural use. Planning Subarea 4.2 leads all planning subareas with 81.6 percent of its land area in agricultural use. It is also the leading row-crop subarea, with 64 percent of its agricultural land in row crop use, contrasted with 36 percent in the remainder of the Basin.

Planning Area 1 (Lake Superior) ranks first in the amount of land in forests, with 78.4 percent of its land area so used, while it ranks last in the amount of urban or agricultural lands. Plan Area 4 (Lake Erie) first in agricultural and urban acres, ranks last in forest area with 22.4 percent of its land area so used.

Detailed statistics are found in Table 13.

SUMMARY AND CONCLUSIONS

Land Use Inventory by Remote Sensing

The expanding human population and man's insatiable appetite for the finite supplies of earth resources have created a critical need for inventorying and monitoring both the renewable and non-renewable resources of our planet. A new and rapidly developing technology for a global-information-system provides man an opportunity to assess, observe, evaluate, and monitor his environment in a time span and with instruments never before available.

The needs of the International Joint Commission and the Environmental Protection Agency for a land use inventory to study sources of pollution in the Great Lakes came at an auspicious time. The results from computer-aided analysis of multispectral scanner data from LANDSAT-1, launched on July 23, 1972, suggested that satellite imagery could be used for rapid preparation of land use inventories of large areas.

This project may have been the first large scale use of computer-aided analysis of LANDSAT-1 MSS data. LANDSAT data from some of the earliest passes over the Great Lakes area were analyzed in the study. At the time the study was initiated and conducted, there was a limited amount of cloud-free LANDSAT data for the Great Lakes Watershed. In fact, for some counties in the Watershed, no cloud-free, good quality MSS data were available even after twenty cycles of satellite passes. The project provided the first opportunity to analyze a large volume of satellite data using the LARSYS computer software system which had been under development and refinement for more than eight years.

Since one of the objectives of the project was to achieve the land use inventory goal at the least expenditure possible, the minimum amount of MSS data, computer time and underflight reference data was used.

Table 13

MAJOR LAND USES, GREAT LAKES REGION

Subarea	Urban-Commercial-Industrial					Agriculture						Forest			No Major Use				
	Residential Acres	Commercial Acres	Subtotal Acres	Subtotal Hectares	Subtotal %	Row Crop Acres	Close Grown Acres	Pasture Acres	Subtotal Acres	Subtotal Hectares	Subtotal %	Acres	Hectares	%	Water Acres	Wetland Acres	Subtotal Acres	Subtotal Hectares	Subtotal %
1.1	207690	196860	404550	163780	3.9	-0-	13200	728190	741390	300150	7.2	8036520	3253650	77.9	522650	617720	1140370	461680	11.0
1.2	139490	41680	181170	73340	2.7	3270	10040	246620	259930	105230	3.9	5591090	2263590	83.0	473090	170180	643270	260430	9.6
Lake Superior Total	347180	238540	585720	237120	3.4	3270	23240	974810	1001320	405380	5.8	13627610	5517240	80.2	995740	787900	1783640	722110	10.5
2.1	324420	35890	360310	145870	3.5	1094570	558150	2385140	4037880	1634760	38.8	5372410	2175060	51.6	426320	205010	631330	255590	6.1
2.2	1064680	342610	1407290	569750	26.5	1654660	408510	1098000	3161180	1279830	59.5	582650	235890	11.0	133120	32150	165270	66910	3.1
2.3	689130	61900	751030	304060	8.2	2342200	455610	3297430	6095170	2467680	66.8	2022600	818860	22.2	172260	86340	258600	104690	2.8
2.4	249870	38270	288140	116650	3.4	265870	89590	1655740	2011200	814250	23.8	5404180	2187920	64.0	455690	279810	735500	297770	8.7
Lake Michigan Total	2328100	478670	2806770	1136330	8.4	5357500	1511860	8436310	15305430	3281930	46.0	13381840	5417730	40.2	1187390	603310	1790700	724960	5.4
3.1	144500	2550	147050	59530	3.5	128050	34060	552400	714510	289270	17.1	3141550	1271880	75.4	163310	660	163970	66380	3.9
3.2	317140	44510	361650	146410	8.1	1279650	273480	1157350	2710470	1097350	60.8	1298460	525690	29.1	73490	17390	90880	36790	2.0
Lake Huron Total	461640	47060	508700	205940	5.9	1407700	307540	1709750	3424980	1386620	39.7	4440010	1797570	51.5	236800	18050	254850	103170	3.0
4.1	541570	180200	721780	292210	17.8	918740	208330	1279920	2407020	974500	59.3	728140	294790	17.9	142050	63110	205160	83060	5.1
4.2	390880	30320	421200	170520	6.6	3373150	570890	1249860	5193880	2102780	81.6	693310	280690	10.9	55250	5040	60290	24400	0.9
4.3	361160	111690	472850	191430	20.3	135990	43100	1014690	1193790	483310	51.2	594260	240590	25.5	50640	20560	71200	28820	3.1
4.4	137180	194110	331290	134120	10.6	206060	16600	942880	1165550	471880	37.4	1539550	623290	49.5	76550	-0-	76550	30990	2.5
Lake Erie Total	1430790	516320	1947120	788280	12.3	4633940	838920	4487350	9960240	4032470	62.7	3555260	1439360	22.4	324490	88710	413200	167270	2.6
5.1	278950	156720	435680	176380	17.6	203300	135740	778390	1117390	452380	45.1	879150	355930	35.5	44570	-0-	44570	18040	1.8
5.2	369590	89400	458990	185820	8.1	430410	161640	1462610	2054660	831840	36.2	2863620	1159360	50.4	228630	76650	305280	123590	5.4
5.3	77060	-0-	77060	31190	2.2	87820	44060	569040	700930	283770	19.7	2378230	962840	66.8	405380	-0-	405380	164120	11.4
Lake Ontario Total	725600	246120	971730	393390	8.3	721530	341440	2810040	3872980	1567990	33.0	6121000	2478130	52.2	678580	76650	755230	305750	6.4
Great Lakes Total Acres	5293310	1526710	6820040			12123740	3023000	18418260	33565000			41125720			3423000	1574620	4997620		
%	6.1	1.8			7.9	14.0	3.5	21.3			38.8			47.5	4.0	1.8			5.8

That is, only every other line and column (or 25%) of the digital data were analyzed. Also, the data from only one satellite pass or date were examined for each county.

It was under these conditions that the project was carried to completion. In many ways this project stands as a milestone in the development and application of remote sensing technology.

Advances in Technology

Although no new technological advances became available in the data acquisition subsystems during the project period, a number of advances occurred in the LARSYS software system. One of the primary objectives at LARS is to advance the technology of data handling and analysis. Some of the most recent improvements include the following:

a) Capability to locate, classify and map areas delineated by irregular boundaries.
b) Capability to overlay multiple sets and sources of data.
c) Development of a technique to extract and classify homogeneous objects from a given data set.
d) Development of a decision-tree classifier to more efficiently and accurately classify a data set.

Future Information Systems

Improvements in three areas provide great promise for the future applications of remote sensing information systems in inventorying and monitoring earth resources:

a) Man's increasing knowledge and understanding of the multispectral properties of earth surface features under a broad array of variable situations, including seasons, atmospheric conditions and geographical setting.
b) Advances in data acquisition subsystems which will provide greater spatial resolution, more frequent coverage, and a broader range of multispectral measurements.
c) Improvements in data handling and analysis subsystems which will offer at less cost per unit of data more timely distribution of data, instantaneous retrieval of data in mass storage, rapid and easy overlay of data from different satellite passes and other sources for the same location, better interactive capabilities between the analyst and the data, and better classification results.

Conclusions

Several conclusions may be drawn from this study:

1. Level I and Level II (as defined in this report) land use categories

may be delineated and mapped quickly by supervised computer-assisted classification of LANDSAT MSS data, providing the following conditions are met:

a. good quality, cloud-free satellite data
b. satellite data available for appropriate season
c. adequate ground observation data available for training the computer.

2. In adjacent counties where land use categories are generally the same, ground observations from one county map may serve as training samples for supervised classification of an adjacent county. In general, quality of classification results decreases with distance from the site from which the training statistics were derived.

3. The quality of supervised classification results in land use inventory studies is greatly dependent upon the availability of sufficient, good quality ground observation data. The more detailed the desired land use survey, the more critical are the training statistics.

4. In many cases the mapping of land use classes might have been improved by examining satellite data from multiple dates.

5. Area estimates may have been improved by analyzing every line and column of satellite data.

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SPECIALIZED LAND USES

Eight specialized land use categories are explored in this study. They are as follows: (1) liquid waste disposal areas, (2) solid waste disposal areas, (3) dredge spoil disposal, (4) deepwell disposal, (5) lakeshore and riverbank erosion, (6) intensive livestock operations, (7) high-density, nonsewered residential areas, and (8) recreational lands.

These eight categories cover the more significant nonpoint sources of pollution from land use activities affecting water quality of the Great Lakes.

DISPOSAL OPERATIONS

Four disposal operations have been identified in this section. They are liquid waste, solid waste, dredge spoil, and deepwell disposal. Liquid waste disposal sites include sanitary landfills, modified landfills, open dumps, and disposal sites for construction debris. Dredging is defined as the process of removing bottom materials from under water and their subsequent disposal. Both nearshore and open water dumping are important, because lake currents can result in nearshore contamination from open water dumping. Deepwell disposal operations involve the injection underground of liquid wastes. Originally used for oil field brines, in the past 30 years there has been an increasing number of other types of wastes injected by deepwell disposal.

Liquid Waste Disposal

Land disposal of liquid waste has been used for some time as an alternative method for disposing of municipal and industrial effluents. This is accomplished by using the soils to filter the wastewaters and sludges applied to it.

Depending on the composition of wastes, site characteristics, and other factors, land application methods may differ. The four primary types of liquid waste disposal utilize either lagoon storage, spray irrigation, septic tank and tile fields, or direct application to the surface of the ground. All four types of discharge require soils with at least moderate permeability. Lagooning of wastes is usually employed where large volumes must be disposed of and has the limitation that during the storage of wastes in lagoons, odors and other nuisances can result. Liquid waste can also be used for spray irrigation in agricultural or silvicultural operations, a process which provides crop nutrients. Where there are moderate amounts of waste to be discharged, septic tanks, in conjunction with tile fields, are most often utilized.

Impacts on water quality will vary according to site characteristics. Potential pollutants are heavy metals, nitrogen (organic nitrogen, nitrate,

TABLE 14 Liquid Waste Disposal Sites[1,2,3b]

		Type of Source			Type of Discharge				
	Total Sites	Municipal	Ind.	Other	Lagoon	Spray Irrigation	Septic Tank Tile Fld.	Ground Surface	Not Identified
Great Lakes Basin	763	434	325	4	208	29	162	66	298
L. Superior	29	2	27	--	12	1	8	8	---
L. Michigan	456	409	43	4	196	28	154	58	20
L. Huron	113	12	101	-	---	--	---	--	113
L. Erie	164	11	153	-	---	--	---	--	164
L. Ontario	1	---	1	-	---	--	---	--	1

and ammonia), phosphorus, other inorganic ions, toxic organic compounds, suspended solids, and pathogens. Ground waters can be affected in different ways according to soil types and the application technique used. The use of lagoon systems is more likely to affect ground water quality than will spray irrigation techniques. However, this depends on the amount and types of effluents supplied and the porosity of the soil.

At the present time, there are over 760 liquid waste disposal operations in the Great Lakes Basin. These are broken down by type for individual Lake basins in Table 14.

Lakes Huron and Erie have the majority of industrial operations, while Lake Michigan is the only basin indicating a large number of municipal disposal sites. It should be noted, however, that the data obtained were not consistent in detail, and comparisons between the Lake basins may not accurately represent actual conditions.

Solid Waste Disposal

Solid waste disposal is the most prominent of the four disposal operations. There are over 2,000 sites in the Basin that have been identified by this study (Table 15). Many of these were not categorized as to the method of disposal. Therefore, it is difficult to determine what percentage of the total number of sites is relatively nonpolluting (sanitary landfills) and what percentage is potentially harmful to water quality (open dumps).

Nearly one-half of the total number of disposal sites are said to be located

TABLE 15 Solid Waste Disposal Sites[2,3c,4,5]

	Total	Sanitary Landfills	Modified or Open Dumps	Other or Unidentified
Great Lakes Basin	2,297	299	785	1,213
Lake Superior	316	18	298	---
Lake Michigan	1,134	244	403	487
Lake Huron	266	22	83	161
Lake Erie	350	15	1	334
Lake Ontario	231	---	---	231

in the Lake Michigan basin. This figure may be misleading, however, due to the fact that data from this area were more detailed than data from other Lake basins.

Many conditions involved in establishing efficient solid waste disposal sites have been frequently ignored in the past. Such conditions include climate, geology, hydrology, and soils.

Climate is of particular concern within the Great Lakes Basin because of the rainfall conditions there. Due to the amount of precipitation in portions of the Basin, leachate production is almost inevitable from solid waste disposal sites. Leachates are produced by water infiltrating and percolating through the landfill and into ground water supplies. Leachates are also produced from saturation by high ground water tables that come into contact with the buried refuse. The types of pollutants that may arise are directly related to the type of refuse present and the manner of disposal. However, leachates are usually characterized as being high in biochemical oxygen demand (BOD), dissolved chemicals (iron, chloride, sodium), hardness, acids, and nitrates (organic decomposition).

In general, the States within the Basin feel that adequate legislation for controlling pollution from solid waste disposal facilities is available. A major concern, however, is the extent of leaching from old abandoned areas (open dumps) and illegal dumping sites used by the public. Data for these facilities is limited, and research into this concern is definitely needed.

The future outlook for solid waste disposal by sanitary landfills shows an increase in its usage for at least the near future. This increase is

TABLE 16 Average Annual Volume of Dredge Spoil Disposal (1961-1970)[6]

	Number of Sites	Average Annual Dredging		Polluted Sediments Requiring Confinement	
		Cu. Meters	Cu. Yards	Cu. Meters	Cu. Yards
Great Lakes Basin	100	6,282,821	8,219,332	4,844,300	6,338,494
Lake Superior	25	798,673	1,044,017	181,215	236,883
Lake Michigan	37	1,133,260	1,481,380	685,790	896,473
Lake Huron	11	393,475	514,683	234,172	306,308
Lake Erie	21	3,679,612	4,815,638	3,488,258	4,565,236
Lake Ontario	6	277,801	363,614	254,865	333,594

partially due to the low costs and simple operation of landfills. Other acceptable methods of solid waste disposal (i.e., incineration, composting, shredding) have been used to a lesser extent primarily because of economic factors. It should be pointed out, however, that the impact of energy shortages may decrease the need for dumps and landfills. Use of solid wastes as heat sources for energy generation may become increasingly important in the future.

Dredge Spoil Disposal

Dredging is the process of excavating bottom material from under water and disposing of it in suitable areas to insure that harbors will have sufficent width and depth for commercial and recreational boating. This removal includes the soft sediments and/or the hard bottoms of limestone and compacted clays.

Due to population and industrial development in the Basin, some of the sediment that is removed by dredging activities has been polluted by municipal, industrial, and agricultural activities. Potential pollutants that are common to the affected sediments include nitrates, phosphates, organic matter, pH, alkalinity, cholrides, iron, oil and grease, mercury, lead, and zinc. Federal legislation concerned with polluted dredge spoil was enacted in 1970 (P.L. 29-611). Section 123 of this law specifically deals with requirements for confined disposal areas and restrictions on open-lake disposal of polluted dredge spoil. However, most dredge spoil material excavated in the Basin continues to be disposed of in open-lake areas. As of July 1974, only 55 of 100 dredging operations were in the confined disposal site program.

In considering the future outlook for dredging activities, it is unlikely that any major work will be done in the Basin in the near future unless larger locks are constructed. If this occurs, larger ships will be utilizing the facilities and there will be a demand for deeper and wider harbors. Because

TABLE 17 Deepwell Disposal Sites [2,3d]

	Total	Type of Waste		
		Brine	Industrial	Other
Great Lakes Basin	83	52	20	11
Lake Superior	0	--	--	--
Lake Michigan	29	14	13	2
Lake Huron	38	26	6	6
Lake Erie	16	12	1	3
Lake Ontario	--	--	--	--

commercial navigation has decreased considerably in the Great Lakes Basin during recent years, the level of annual dredging may be significantly altered in the future. This depends on the level of mineral extraction, the economic viability of shipping, and the development of industries where shipping is the most economic form of transport.

In all likelihood, if economic development continues to occur in the Basin, there will be an increase in the percentage of polluted sediments. If sediment pollution does increase, further increases in dike disposal is likely in the near future, raising the potential for nearshore water pollution if dike spoils are not properly handled. Conversely, if proper technology is applied to controlling pollutant loss from disposal areas, the pollution potential may be greatly reduced.

Of the 100 harbors and channels that are dredged periodically, 70 were classed as polluted or partially polluted. On a volumetric basis, as shown in Table 16, the past average annual amount of dredge spoil (1961-1970) handled in the Basin has been 6,282,821 cubic meters (8,219,332 cubic yards).

Data were generally not available concerning private dredging activities. The amounts generated by each private operation are quite small compared with major harbor activities. However, in the aggregate they may have important water quality impacts.

The amount and length of artificial fill areas along the Great Lakes shoreline is not sufficiently defined at the present time. In this report, artificial fill areas include manmade landfills created by dredging or other means for additional land development, or the process of replenishing beaches by the deposition of dredged materials. The length of artificial fill areas, as defined in the Great Lakes Basin Framework Study, Appendix 12, "Shore Use and Erosion,"[7] is 295.7 kilometers (183.7 miles).

Deepwell Disposal

Deepwell waste disposal techniques have been practiced for decades, primarily for the disposal of brines produced in oil field operations. Since about 1950 deepwell disposal of industrial wastes has become an increasingly popular solution for elimination of toxic or noxious liquids. Most of the wastes injected are high-strength organics, caustics, acids or other toxic materials, and processed brines (Table 17). These wastes are foreign to the receiving formations and contaminate such formations; however, the formations act as storage reservoirs for wastes and should prevent contamination of other resources or areas.

Ideally, the receiving formation is bounded both above and below by formations of low vertical permeability. Even with such precautions, upward flow can occur if high injection pressures are used and hydrofracturing has occured.

In general, the states in the Basin discourage the use of deepwell disposal. Control measures vary from prohibition of any subsurface injection (Wisconsin) to a permit system (Michigan).

EROSION

Erosion along the land-water interface occurs in two particular areas, lakeshore and riverbank zones. On one hand, lakeshore erosion contributes sizable amounts of sediment into the nearshore area. However, most of this sediment does not contain nutrients or pesticide materials, and therefore its major effect on surface waters is in increasing nearshore turbidity and smothering of benthic biota. Riverbank erosion, on the other hand, contributes sizable amounts of nutrient and pesticide materials from surrounding lands captured in the sediment. In balance, riverbank erosion may have significantly greater impacts upon water quality in the Great Lakes than lakeshore erosion.

Other types of erosion include sheet, rill, and small gully erosion which occur on upland areas. Sediment, plant nutrients, and pesticide materials are transported to streams, inland lakes, and the Great Lakes as a result of these forms of erosion.

Lakeshore Erosion

Three primary factors control the amount of erosion on the Great Lakes' shorelines. The first is the physical nature of the shoreline. Table 18 gives detailed information of the major shore types and this data is also shown graphically on Figure 19.

A second factor contributing to shoreline erosion is the combination of lake levels and storm intensity and frequency. As a rule, the higher the lake level and the more frequent and intense the storms, the greater the erosive force and the more rapidly lakeshore erosion and recession will occur. At present the Great Lakes are experiencing unusually high lake levels and consequently the erosion of shorelines is greater than normal.

TABLE 18 Great Lakes Shore Type (in miles)[7]

Type of Shore	Great Lakes Basin	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Artificial fill area	183.7	6.1	67.4	3.1	98.9	14.4
Erodible high bluff	554	59.5	273.6	34.7	146.4	39.8
Nonerodible high bluff	289.1	225.2	46.9	0	2.0	15.0
Erodible low bluff	634	257.0	118.9	69.0	86.6	102.5
Nonerodible low bluff	371.4	170.1	24.7	64.0	6.1	106.5
High sand dune	143.6	4.0	139.6	0	0	0
Low sand dune	181.8	77.6	73.4	18.4	12.4	0
Erodible low plain	623	61.7	287.5	195.4	63.3	15.1
Nonerodible low plain	243.6	23.4	173.5	45.4	1.3	0
Wetlands	419.9	27.4	94.5	226.2	36.5	35.3
Wetlands/erodible plain	55.3	0	51.8	0	3.5	
Wetlands/erodible low bluff	10.2	0	10.2	0	0	
Total shore miles	3,715.8	912.0	1,362.0	656.2	457.0	328.6

Kilometers (km) = Miles (mi) x 1.609

The third controlling factor is the variety, concentration, and location of shoreline land use. Improper construction methods and location and incompatible shoreline development serve only to exacerbate the natural littoral and shoreline processes.

While there is a dearth of information on streambank erosion, a great deal of research and analysis has been directed towards shoreland erosion (Table 19). However, most of this data is based on economic parameters. Very little research has been conducted on measuring volumetric erosion rates, which are necessary to assess the impact of shoreline erosion on water quality.

Based on data from a survey of shore types through geographic and geological observations, it was determined that the nonerodible coastline encompassed 24.3 percent, or 1,455.6 kilometers (904 miles) of the total shoreland area.[7] Erodible zones excluding sand dunes incorporated 66.7 percent, or 3,999.9 kilometers (2,486 miles) of the shoreland area. The sand dunes accounted for about 8.7 percent or 523.8 kilometers (325.4 miles), of the shoreland area. If we include sand dunes in the erodible categories, 75.6 percent of Great Lakes shoreline is subject to erosion. Thus, out of the 5,982.4 kilometers (3,715.8 miles) of shoreline, 4,4524.0 kilometers (2,811.7 miles) is subject to some form of erosion. The estimate of erodible low plain may understate the actual amount, based on comments received in the review of this report.

According to the economic loss criteria, of the existing 5,661.6 kilometers (3,518.7 miles) of shoreline in the Basin (not including St. Marys, St. Clair, Detroit or Niagara Rivers), 47 percent, or 2,680.7 kilometers (1,666 miles) is not subject to flooding or erosion, while the remaining 53 percent is subject to certain forms of flooding and erosion. Critical erosion affects

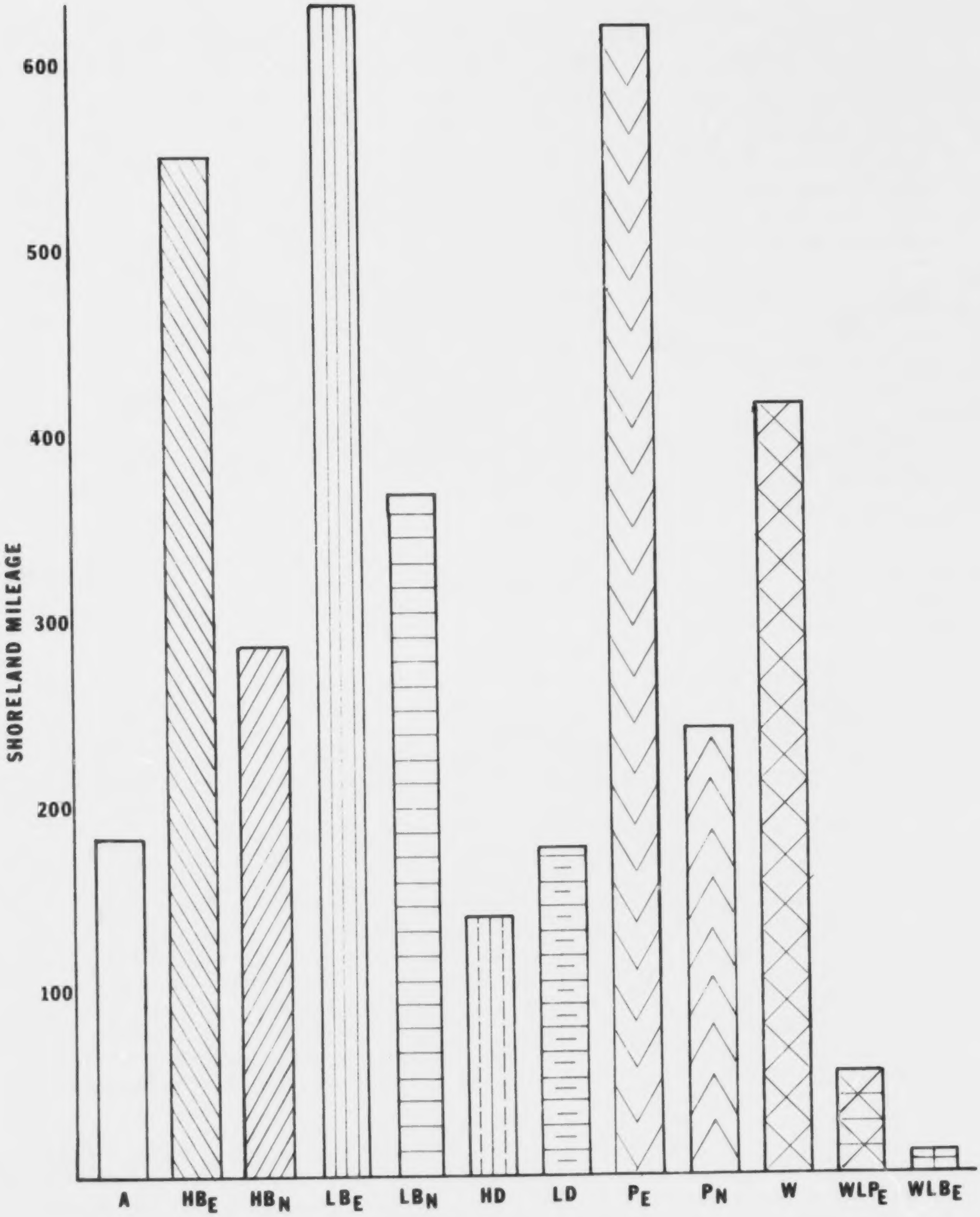

FIGURE 19 Distribution of Great Lakes Shore Types[7]

Table 19 GREAT LAKES SHORELINE EROSION [7]

	Lake Superior			Lake Michigan			Lake Huron		
	Shoreline		% of	Shoreline		% of	Shoreline		% of
	km	mi	total	km	mi	total	km	mi	total
Existing miles of shoreline [1/]	1,468	912	100	2,192	1,362	100	909.1	565	100
Critical erosion areas	46.2	28.7	3.1	210	130.1	9.5	12.9	8	1.4
Noncritical erosion	205.8	127.9	14	736	457.4	33.5	248.4	154.4	27.3
Protected shoreline	8.7	5.4	.5	261	162	11.8	0	0	0
Shoreline subject to flooding	18.9	11.8	1.2	226	140.7	10.3	120.5	74.9	13.2
Shoreline not subject to flooding or erosion	1,188	738.2	80.9	759	471.8	34.6	527.3	327.3	58

	Lake Erie			Lake Ontario			Great Lakes Basin		
	Shoreline		% of	Shoreline		% of	Shoreline		% of
	km	mi	total	km	mi	total	km	mi	total
Existing miles of shoreline [1/]	627.7	390.1	100	465.9	289.6	100	5661.6	3518.7	100
Critical erosion areas	33.1	20.6	5.2	27	16.8	5.8	328.6	204.2	5.8
Noncritical erosion	137.2	85.3	21.9	271.9	169	58.3	1599.3	994	28.2
Protected shoreline	246.3	153.1	39.2	41.2	25.6	8.8	556.9	346.1	9.8
Shoreline subject to flooding	100.7	62.6	16.1	29.6	18.4	6.3	496.2	308.4	8.8
Shoreline not subject to flooding or erosion	110.2	68.5	17.6	96.2	59.8	20.6	2,680.6	1,666	47.3

[1/] Does not include St. Marys, St. Clair, Detroit or Niagara River Mileage

TABLE 20 Michigan High Risk Shoreline Erosion Mileage[8]

	Developed	Undeveloped	Total
Lake Superior	50.1	109	159.1
Lake Michigan	383.5	167.7	551.2
Lake Huron	92.8	8.9	101.7
TOTAL	526.4	285.6	812.0

Kilometers (km) = Miles (mi) x 1.609

5.8 percent of the shoreline, or 328.6 kilometers (204.2 miles). Shoreline subject to noncritical erosion amounts to 28.2 percent of the total or 1,599.3 kilometers (994 miles). Both of these categories of erosion account for 34.4 percent of the shoreline in the Basin, or 1,927.9 kilometers (1,198.2 miles).

Protected shoreline accounts for 9.8 percent of the total and encompasses 556.9 kilometers (346.1 miles). This includes areas protected by seawalls of diking systems which prevent erosion from occurring. Shorelines which are subject to flooding account for 8.8 percent, or 496.2 kilometers (308.4 miles) in the Basin.

It must be remembered that these estimates understate the amount of geological erosion and sedimentation occurring. Because they are based on erosion causing loss of property (e.g., buildings), there is not a direct correlation to the amount of geological erosion occurring in undeveloped areas. The vast majority of shoreland areas not included in the critical erosion catagories in the aggregate may account for more of the sedimentation occurring from erosion than what comes from critically erodible zones as defined by the economic loss criteria.

Recently, one study has estimated the extent of geologic erosion (Table 20). In 1973, the State of Michigan Water Development Services conducted a detailed survey of geologic erosion of the Michigan shorelines (including Lakes Superior, Michigan, and Huron). These data may give a more accurate estimate of the actual erosion taking place on those Lakes. The data for the Michigan portion of the Great Lakes shorelines show that 1,307 kilometers (812 miles) are undergoing high risk erosion. More than one-third of this distance was in undeveloped areas (which were not considered in the economic loss estimates).

Riverbank Erosion

Riverbank erosion can be caused by direct abrasion, undercutting, or sloughing, or from a combination of these processes. It is a natural geologic phenomenon by which valley development occurs as a result of gradual widening. Existing flood plain and land along the valley sides

TABLE 21 Total Length of Streambank Erosion on Great Lakes[9]

	Superior		Michigan		Huron		Erie		Ontario		Basin Total	
	km	mi	km	mi	km	mi	km	mi	km	mi	km	mi
Moderate	1,544	959	4,264	2,650	1,742	1,083	3,277	2,037	2,059	1,280	12,886	8,009
Severe	758	471	1,286	799	1,007	626	987	614	371	231	4,409	2,741
TOTAL	2,302	1,430	5,549	3,449	2,749	1,709	4,265	2,651	2,430	151	17,295	10,750

are lost or altered by lateral cutting and undermining. Serious damages can also result when man's activities accelerate this natural process.

In addition to the obvious loss of land and natural resources, agricultural and urban improvements on this land also result in additional sediment, nutrients, and other contaminants entering the waters.

The effects of riverbank erosion on water quality are particularly noticeable in newly developing urban areas. Urban development usually leads to increasing runoff due to the decline in permeable surfaces which can absorb storm waters. Increased runoff can lead to greater bank cutting and sloughing. The resulting sediment loads from eroding riverbanks in urban environments can become a major source of sediment in water. The total length of streambank erosion for each of the lakes is shown in Table 21.

Estimates range from an average of 2.46 metric tons of sediment per square kilometer (7 tons per square mile) eroded from streambanks yearly to as high as 15.8 metric tons per square kilometer (45 tons per square mile).[9] An average of 9.5 metric tons per square kilometer (27 tons per square mile) for the entire Great Lakes Basin was found. The erosion is summarized in bank lengths (a length of streambank erosion on one side of a stream channel). The term "severe streambank erosion" is a working term to separate those areas which appear to have sizable damages, i.e., damages detrimental to one or more of a wide variety of uses. Furthermore, damage by severe streambank erosion protection is justified. Moderate streambank erosion includes those areas that have some damage, but under present conditions do not appear to warrant further study because installation of a protective measure will not produce sufficient benefits.

INTENSIVE LIVESTOCK OPERATIONS

In recent years attention has been given to the water quality problems caused by agricultural wastes due to changes primarily in agricultural production practices. For economic reasons, livestock production had become increasingly concentrated in larger operations, increasing the confinement of the numbers of animals per livestock operation.

TABLE 22 Number of Intensive Livestock Operations[3a,10]

	Poultry (10,000 or more)	Cattle (100 or more)	Swine (200 or more)	Total
Great Lakes Basin	638	9,394	2,767	12,799
Lake Superior	3	84	3	90
Lake Michigan	280	5,094	1,477	6,851
Lake Huron	51	704	98	853
Lake Erie	206	1,816	1,145	3,167
Lake Ontario	98	1,696	44	1,838

The following definition of an intensive livestock operation was established for this study: "A facility capable of holding animals on land not used for the growing of crops or vegetation." The numbers of animals used for this definition are 100 or more head of cattle (available data did not allow identification for beef and dairy), 200 or more swine, and 10,000 or more poultry. These standards were presented by Dr. R.C. Loehr for intensive animal feedlots, based upon what was felt to be an appropriate size for a large single enterprise, operating at a respectable profit.[3a]

It should be noted that the definition of an intensive livestock operations is arbitrary. If one uses the definition of a feedlot that appears in the EPA regulations for the feedlot point source category (i.e., operations having 1,000 head of beef cattle, 700 head of dairy cattle, 2,500 swine, 10,000 sheep, 55,000 turkeys, 5,000 ducks, or poultry operations with a liquid system) there are very few intensive livestock operations in the Basin.

According to Dr. Loehr's standards, there are 12,799 intensive livestock operations in the Great Lakes Basin, of which 638 are poultry operations, 9,394 are cattle operations, and the remaining 2,767 are swine operations (Table 22). These estimates are based on information contained in the 1969 Census of Agriculture.

HIGH DENSITY, NONSEWERED RESIDENTIAL AREAS

There is an increasing concern over other aspects of sewage disposal besides those relating strictly to public health. Sewage effluents can have significant impacts on water quality and the overall environment. While one may be content from a public health viewpoint with 5.8 percent of the urban housing in the Basin not being serviced by public systems, the same 5.8 percent may incur significant water quality impacts in terms of nutrient enrichment of streams and lakes, heavy concentrations of certain chemical compounds detrimental to surface water uses, and changes in the general

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	km	mi	km	mi	km	mi	km	mi	km	mi	km	mi
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TABLE 23 High-density, Nonsewered Residential Areas[11]

		Nonsewered Households					
		Urban		Rural Non-Farm		Combined	
	Total Housing Units	Number	% Total Housing Units	Number	% Total Housing Units	Number	% Total Housing Units
Great Lakes Basin	9,346,529	550,349	5.8	1,280,629	13.7	1,831,478	19.5
Lake Superior	183,348	4,278	3	50,482	29	54,760	31
Lake Michigan	4,389,252	254,597	5	511,486	12	766,083	17
Lake Huron	400,960	36,542	9	153,121	38	189,663	47
Lake Erie	3,570,660	220,480	6	359,723	9	580,203	15
Lake Ontario	802,309	34,952	4	205,817	25	240,769	30

aesthetic characteristics of nearby aquatic environments. While there are no figures on the magnitude of pollution associated with these systems, it could be locally severe. The Basin does have areas with sandy loam loils which are suitable for septic tank systems with little adverse impact. However, throughout portions of the Basin study area, soil and ground water conditions pose severe limitations on the use of on-site disposal systems.

In searching the U.S. Bureau of the Census Housing Characteristics Reports for 1970, it was found that in the Great Lakes Basin there are 9,346,529 sewered and nonsewered housing units. The 1,831,478 nonsewered housing units make up 19.5 percent of this total figure. Of those nonsewered units, 5.8 percent or 550,849 are in urban areas, and 13.7 percent or 1,280,629 are in rural nonfarm areas. Details are given in Table 23.

With future urbanization expected in the Basin, it is assumed that a decrease in nonsewered housing in urban areas will occur due to expansion of public sewage systems. With continued growth occurring in nonfarm rural areas, the feasibility of providing extended public sewage systems is likewise enhanced. Also, with stepped up enforcement of environmental statutes regulating wastewater disposal, the detection of faulty septic systems and better operation of on-site disposal methods should result.

RECREATIONAL LAND USE

The Great Lakes Region possesses diverse and outstanding natural features: Great Lakes water surface and shoreline, thousands of inland lakes and associated beaches, mountains and rolling morainic hills, extensive forests, streams and marshland with relatively high-quality waters, and many islands, inlets, and bays. While a few of these resources are near the large urban centers in the southern portion of the Region, most are located on the drainage areas of Lake Superior, Lake Ontario, and the northern parts of Lakes Michigan and

TABLE 24 Summary of Recreational Areas and Activities [12]
(in acres)

	Water-Oriented Activities			Other Summer Activities			
	Swimming	Picnicking	Camping	General Parking	Boating Parking	Playfield	Golf
Gt. Lks. Basin	2,400	18,560	14,290	3,850	2,240	30,490	63,860
Lake Superior	290	1,500	2,070	220	280	910	1,800
Lake Michigan	1,120	9,080	4,380	1,220	1,250	15,620	21,590
Lake Huron	110	1,110	1,430	410	260	680	1,060
Lake Erie	750	4,120	2,920	1,530	410	12,180	33,640
Lake Ontario	130	2,750	3,490	470	40	1,100	5,770

	Winter Activities		Water Surface		
	Skiing	Sledding	Ice Skating	Boating	Total Area
Gt. Lks. Basin	2,350	0	1,210	4,231,000	4,370,250
Lake Superior	1,080	0	30	1,428,000	1,436,180
Lake Michigan	890	0	810	1,518,000	1,573,960
Lake Huron	60	0	0	450,000	455,120
Lake Erie	300	0	340	457,000	513,190
Lake Ontario	20	0	30	378,000	391,800

Hectare (ha) = Acres (acre) x 0.405

Huron. In general, one of the most critical needs for recreation in the Basin is the provision of high capacity day use and weekend use facilities close to major metropolitan areas. Accessibility to all city residents must also be provided. The shorelines and islands of the Great Lakes offers great opportunity for recreation, but there is a constant effort to prevent industrial, commercial, and private ownership from restricting public access to the regional land and water resources.

Table 24 gives detailed information on those areas which now provide or have great potential for providing recreational opportunities in the Great Lakes Region. It should be noted that these sites also have the potential to create water quality problems through the poor waste treatment and excessive erosion which often accompany such concentrated use.

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MATERIALS USAGE

INVENTORY OF PRESENT MATERIALS USAGE

The Great Lakes Basin representing the United States side encompasses 191 counties located in eight states. The Agricultural Census for the United States either does not provide the data or combines the information so that census statistics for four counties in the Basin are not reported as such. These counties are: Keweenaw and Crawford in Michigan, Cook in Minnesota, and Menominee in Wisconsin. Thus, the information presented in this report is based on 187 counties, rather than the total 191 counties.

Agriculture within the Basin is widely varied. The land area in the Great Lakes Basin (187 counties) encompasses over 33 million total hectares (82 million acres), with 13 million hectares (33 million acres) in farmland, 10 million hectares (24 million acres) in farm cropland, and 7 million hectares (17 million acres) in harvested farm cropland. This vast and varied expanse of land begins with the cut-over and forest lands on the Canadian border at the west end of Lake Superior. It extends south through Wisconsin dairy land into the cornbelt, then northeast through all of Michigan, and east through Indiana and Ohio. Finally, it hugs the Lakes continuing through the dairy, fruit, and vegetable regions of Pennsylvania and New York, ending at the Adirondacks. With this type of situation, generalizations are hard to provide, and summaries and comparisons are very difficult to make representative and meaningful. The trends and projections provided could have been improved if time and resources had permitted greater input on the part of competent and knowledgeable personnel at the State, county, and local levels.

An inventory and analysis of materials usage was made based on personal interviews, correspondence, and statistics as available from agricultural statistics, census information, state highway departments, universities, private companies, and state and federal agencies. Background for the analysis is presented in the methodology section. Tables 25 to 29 summarize the findings of this inventory and analysis. Detailed statistics are shown on Table 30.

TABLE 25 Chemicals Used by Class and By Harvested Cropland Acre

	Chemicals Used										
	Herbicides		Insecticides		Fungicides		Total Chemicals Used			Chemicals Per Harvest Acre	
	CWT	% of Total Chem. Used	CWT	% of Total Chem. Used	CWT	% of Total Chem. Used	CWT	Pounds	Tons	Pounds	Index
PSA 1.1	955.4	46	898.6	43	219.4	11	2,073.4	207,340	104	1.18	44
PSA 1.2	400.0	39	458.0	44	177.0	17	1,035.0	103,500	52	1.16	44
Plan Area 1.0	1,355.4	44	1,356.6	44	396.4	12	3,108.4	310,840	156	1.18	44
PSA 2.1	25,860.5	53	16,359.7	33	6,759.2	14	48,979.4	4,897,940	2,449	2.20	83
PSA 2.2	34,250.9	77	7,897.4	18	2,239.7	5	44,388.0	4,438,880	2,219	2.21	83
PSA 2.3	52,864.7	57	23,620.0	26	16,078.5	17	92,563.2	9,256,320	4,628	3.27	123
PSA 2.4	7,499.2	34	6,866.4	31	7,630.4	35	21,996.0	2,199,600	1,100	4.45	168
Plan Area 2.0	120,475.3	58	54,743.5	26	32,707.8	16	207,926.6	20,792,660	10,396	2.75	103
PSA 3.1	2,174.9	55	1,129.7	29	643.6	16	3,948.2	394,820	198	2.02	76
PSA 3.2	29,407.5	79	5,204.8	14	2,433.9	7	37,046.2	3,704,620	1,852	2.52	95
Plan Area 3.0	31,582.4	77	6,334.5	15	3,077.5	8	40,994.4	4,099,440	2,050	2.46	92
PSA 4.1	17,625.7	75	4,513.5	19	1,458.7	6	23,597.9	2,359,790	1,180	2.21	83
PSA 4.2	66,023.3	83	10,168.9	13	3,350.6	4	79,542.8	7,954,280	3,977	2.09	79
PSA 4.3	3,772.0	54	1,876.8	27	1,378.0	19	7,026.8	702,680	351	2.25	85
PSA 4.4	6,393.7	20	16,097.5	50	9,786.8	30	32,278.0	3,227,800	1,614	6.82	256
Plan Area 4.0	93,814.7	66	32,656.7	23	15,974.1	11	142,445.5	14,244,550	7,122	2.52	95
PSA 5.1	7,035.9	40	5,070.8	29	5,583.5	31	17,690.2	1,769,020	885	3.11	117
PSA 5.2	12,956.2	35	12,744.2	34	11,727.5	31	37,424.9	3,742,490	1,871	3.78	142
PSA 5.3	3,146.0	64	1,683.2	34	74.0	2	4,903.2	490,320	245	1.19	45
Plan Area 5.0	23,138.1	39	19,498.2	32	17,385.0	29	60,021.3	6,002,130	3,001	3.05	115
TOTAL	270,365.9	60	114,589.5	25	69,540.8	15	454,496.2	45,449,620	22,725	2.66	100

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405

kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

TABLE 26 Manure Tonnage by PSA, Plan Area, and Kind of Livestock

	Cattle		Horses		Chickens		Swine		Sheep		Turkeys		
	Tons	% Total Tons	Tons	% Total Tons	Tons	% Total Tons	Tons	% Total Tons	Tons	% Total Tons	Tons	% Total Tons	Total Tons of Manure
PSA 1.1	731,205	87	83,211	10	9,904	1	4,700	1	4,509	1	503	0	834,031
PSA 1.2	299,130	85	44,768	13	2,983	1	1,764	0	4,245	1	0	0	352,890
Plan Area 1.0	1,030,335	87	127,979	11	12,887	1	6,464	0	8,754	1	503	0	1,186,921
PSA 2.1	9,571,400	93	143,762	1	61,470	1	518,536	5	24,118	0	3,750	0	10,323,056
PSA 2.2	4,127,793	76	730,518	13	109,267	2	425,978	8	37,568	1	2,570	0	5,433,964
PSA 2.3	7,319,800	69	1,552,233	14	197,756	2	1,244,456	12	222,789	2	132,180	1	10,669,214
PSA 2.4	1,797,969	83	284,496	13	31,746	1	41,572	2	18,490	1	6,307	0	2,180,580
Plan Area 2.0	22,816,962	80	2,711,009	9	400,239	1	2,230,542	8	302,965	1	144,807	1	28,606,524
PSA 3.1	789,999	85	101,486	11	6,323	1	15,291	2	10,465	1	0	0	923,564
PSA 3.2	2,812,566	82	413,101	12	65,025	2	121,681	3	35,581	1	0	0	3,447,954
Plan Area 3.0	3,602,565	82	514,587	12	71,348	2	136,972	3	46,046	1	0	0	4,371,518
PSA 4.1	2,583,516	72	715,630	20	37,987	1	145,323	4	113,344	3	0	0	3,595,530
PSA 4.2	3,956,796	63	526,447	8	268,180	4	1,161,675	19	265,830	4	134,360	2	6,313,288
PSA 4.3	1,278,460	76	326,503	19	30,638	2	30,262	2	14,651	1	7,542	0	1,688,056
PSA 4.4	2,195,089	85	331,283	13	28,280	1	16,108	1	15,332	0	3,928	0	2,590,020
Plan Area 4.0	10,013,861	71	1,899,593	13	365,085	3	1,353,368	9	409,157	3	144,420	1	
PSA 5.1	1,877,209	84	266,195	12	27,498	1	21,704	1	48,617	2	503	0	2,241,728
PSA 5.2	3,930,238	86	460,834	10	93,364	2	31,581	1	46,109	1	4,468	0	4,566,594
PSA 5.3	2,420,802	93	148,695	6	9,818	1	4,584	0	2,571	0	3,142	0	2,589,612
Plan Area 5.0	8,228,249	88	875,724	9	130,680	2	57,869	1	97,299	1	8,113	0	9,397,934
TOTAL	45,691,972	79	6,128,892	10	980,239	2	3,785,215	6	864,221	2	297,842	1	57,748,381

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405

kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

TABLE 27 Intensity of Manure and Primary Nutrients per Harvested Acre

	Harvested Cropland Acres	Tons of Livestock Manure	Tons Manure/ Harvested Acre	Manure Production Index	Primary Nutrients in Manure (tons)				Pounds Primary Nutrients/ Harvested Acre	Manure Primary Nutrients Index
					(N)	(P_2O_5)	(K_2O)	Total		
PSA 1.1	175,073	834,031	4.76	141	4,916	872	4,255	10,043	115	140
PSA 1.2	88,955	352,890	3.97	118	2,097	370	1,822	4,289	96	117
Plan Area 1.0	264,028	1,186,921	4.50	134	7,013	1,242	6,077	14,332	109	133
PSA 2.1	2,226,946	10,323,056	4.64	138	58,541	10,753	51,159	120,453	108	132
PSA 2.2	2,009,410	5,433,694	2.70	80	32,560	5,981	27,409	65,950	66	80
PSA 2.3	2,830,585	10,669,214	3.77	112	66,190	12,402	54,020	132,612	94	115
PSA 2.4	493,782	2,180,580	4.42	131	13,092	2,331	11,173	26,596	108	132
Plan Area 2.0	7,560,723	28,606,524	3.78	112	170,383	31,467	143,762	345,612	91	111
PSA 3.1	195,595	923,564	4.72	140	5,441	959	4,745	11,145	114	139
PSA 3.2	1,469,446	3,447,954	2.35	70	20,722	3,734	17,583	42,039	57	70
Plan Area 3.0	1,665,041	4,371,518	2.63	78	26,168	4,692	22,331	53,191	64	78
PSA 4.1	1,068,323	3,595,530	3.37	100	22,308	3,893	19,028	45,229	85	104
PSA 4.2	3,802,981	6,313,288	1.66	49	41,708	8,332	31,419	81,459	43	52
PSA 4.3	312,904	1,688,056	5.39	160	10,364	1,830	8,746	20,940	134	163
PSA 4.4	473,598	2,590,020	5.47	162	15,377	2,711	13,290	31,378	133	162
Plan Area 4.0	5,657,806	14,185,484	2.51	74	89,735	16,729	72,480	178,944	63	77
PSA 5.1	567,936	2,241,728	3.95	117	13,576	2,387	11,649	27,612	97	118
PSA 5.2	990,426	4,566,594	4.61	137	27,519	4,923	23,340	55,782	113	138
PSA 5.3	411,461	2,589,612	6.29	187	14,843	2,633	13,084	30,560	149	182
Plan Area 5.0	1,969,823	9,397,934	4.77	142	55,937	9,944	48,073	113,954	116	141
TOTAL	17,117,421	57,748,381	3.37	100	349,236	64,074	292,723	706,033	82	100

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405

kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

TABLE 28 Commercial Fertilizer: Use and Nutrient Intensity

	Commercial Fertilizer (tons)	Percent Liquid	Commercial Fertilizer Harvest/Acre		Primary Nutrients in Commercial Fertilizer						Total Tons	Primary Nutrient/ Harvest Acre	
					(N)		(P_2O_5)		(K_2O)				
			Lbs.	Index	tons	%	tons	%	tons	%		Lbs.	Index
PSA 1.1	12,820	24	146	45	2,734	39	2,036	29	2,289	32	7,068	81	53
PSA 1.2	4,040	16	91	28	652	33	633	32	695	35	1,980	45	29
Plan Area 1.0	16,860	22	128	40	3,386	37	2,669	80	2,993	33	9,048	69	45
PSA 2.1	234,908	19	211	66	31,936	26	34,278	28	55,741	46	121,955	110	72
PSA 2.2	348,908	37	347	108	60,938	36	45,217	27	61,903	37	168,058	167	109
PSA 2.3	487,799	24	345	107	75,312	33	73,002	32	79,295	35	227,609	161	105
PSA 2.4	75,771	16	307	96	12,252	33	11,880	32	12,996	35	37,128	150	98
Plan Area 2.0	1,147,386	26	304	95	180,438	32	164,377	30	209,935	38	554,750	147	96
PSA 3.1	20,784	16	213	66	3,327	33	3,226	32	3,530	35	10,083	103	67
PSA 3.2	292,473	16	398	124	47,293	33	45,861	32	50,159	35	143,313	195	127
Plan Area 3.0	313,257	16	376	117	50,620	33	49,087	32	53,689	35	153,396	184	120
PSA 4.1	197,618	16	370	115	31,956	33	30,986	32	33,891	35	96,833	181	118
PSA 4.2	651,276	28	343	107	103,808	31	105,889	32	122,129	37	331,826	175	114
PSA 4.3	42,726	2	273	85	5,925	28	7,047	34	7,980	38	20,952	134	88
PSA 4.4	71,332	8	301	94	8,401		10,102	37	8,950	32	27,453	116	76
Plan Area 4.0	962,952	23	340	106	150,090	32	154,024	32	172,950	36	477,064	169	110
PSA 5.1	108,277	7	381	119	13,092	31	15,624	37	13,512	32	42,228	149	97
PSA 5.2	168,436	7	340	106	20,366	31	24,304	37	21,020	32	65,690	133	87
PSA 5.3	27,360	7	133	41	3,308	31	3,948	37	3,414	32	10,670	52	34
Plan Area 5.0	304,073	7	309	96	36,766	31	43,876	37	37,946	32	118,588	120	78
BASIN	2,744,528	22	321	100	421,300	32	414,033	32	477,513	36	1,312,876	153	100

kilograms = pounds (lbs) X 0.453
kilograms = tons (ton) X 907.2
metric tons = tons X 0.907

TABLE 29 Lime and Road De-Icers Used Per Harvested Acre and Index of Use

	Lime per Harvested Cropland Acre			Road De-Icers per Acre Total Land Area		
	Total Tons	Pounds	Index	Total Tons	Pounds	Index
PSA 1.1	24,369	278	164	20,266	4.7	11
PSA 1.2	7,737	174	102	46,183	15.1	36
Plan Area 1.0	32,106	243	143	66,449	9.0	22
PSA 2.1	81,475	73	43	86,379	16.5	40
PSA 2.2	230,117	229	135	319,912	122	292
PSA 2.3	321,666	227	134	189,667	42.1	101
PSA 2.4	59,474	241	142	64,813	15.9	38
Plan Area 2.0	692,732	183	108	660,771	41	98
PSA 3.1	6,281	64	38	34,294	18.6	45
PSA 3.2	22,290	30	18	71,909	32.2	77
Plan Area 3.0	28,571	34	20	106,203	26.1	63
PSA 4.1	48,932	92	54	175,619	87.9	211
PSA 4.2	306,809	161	95	115,170	36.4	87
PSA 4.3	75,890	485	285	136,046	117.5	282
PSA 4.4	78,788	333	196	116,582	75.9	184
Plan Area 4.0	510,419	180	106	543,417	69.1	166
PSA 5.1	66,825	235	138	185,592	150.4	360
PSA 5.2	93,608	189	111	123,561	43.3	109
PSA 5.3	34,740	169	99	29,863	17.4	42
Plan Area 5.0	195,173	198	116	339,016	59.7	143
TOTAL	1,459,001	170	100	1,715,856	41.7	100

kilograms (kg) = pounds (lb) x 0.454
kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

TABLE 30 Great Lakes Basin Material Usage Inventory

Agricultural Chemicals, Manures, Fertilizers, Lime and Highway De-Icing Compounds

PLANNING AREA: Great Lakes Water Basin Summary STATE: __________

PLANNING SUBAREA: __________ COUNTY: 191 County Totals

TABLE 1--ESTIMATED AMOUNTS OF CHEMICALS USED ON CROPS, 1972

Crop Group or Crops	Herbicides Acres Treated	Herbicides Amount Used 100 lbs	Insecticides Acres Treated	Insecticides Amount Used 100 lbs	Fungicides Acres Treated	Fungicides Amount Used 100 lbs
Corn	5549139	152595.9	1233143	18494.1		
Grains	1735454	8671.3	578483	5778.9		
Hay or Grass Silage	1386610	13855.9	1155508	11550.8		
Pastured Cropland	747433	7465.1	747433	7465.1		
Other Field Crops	3071486	65331.6	259080	10771.9	76487	11372.0
Vegetables	402424	12427.3	374291	19644.9	377032	15053.1
Orchards						
Berries	205652	9516.2	240955	40883.8	246916	43115.7
Nursery, Greenhouse						
Other Crops						
Totals	13098208	270365.9	4588893	114589.5	700335	69540.8
Total Herbicides, Insecticides, Fungicides: 100 lbs					18387436	454496.2

TABLE 2--MANURE FROM SWINE

Year	Hog & Pig Inventory Dec. 1	Number Sows Farrowing Dec. 1-May 31 Spring	Number Sows Farrowing June 1-Nov. 30 Fall	Total
1964	2490075	263418	249929	513347
1969	2409844	225020	225884	450904
1972	2553059	255152	258958	514110

Wet Manure Factor: Tons per litter farrowed 3785970

Wet Manure Defecated: Tons, 1972 19037

Nutrients in Wet Manure: Nitrogen, tons 5324

Phosphorus, tons 14376

Potash, tons

TABLE 3--MANURE FROM CATTLE

Year	Total	Number Cattle and Calves: Cows & Heifers Calved	Number Cattle and Calves: Heifers, Steers, Bulls, Calves
1964	5359820	2529837	2829983
1969	4558551	2098534	2460017
1972	4815647	2206015	2609632
Wet Manure Factor: Tons Per Animal		13.14	6.45
Wet Manure Defecated: Tons, 1972		28987031	16832126

Wet Manure Defecated: Tons, 1972 Combined: 45819157

Nutrients in Wet Manure: Nitrogen, tons 257381

Phosphorus, tons 45960

Potash, tons 229804

TABLE 4--MANURE FROM SHEEP AND HORSES

Year	Item	Sheep & Lambs	Horses & Ponies
1964		783829	
1969		642952	139966
1972		536783	479569
Wet Manure Factor: Tons per animal		1.61	12.78
Wet Manure Defecated: Tons, 1972		864221	6128892
Nutrients in Wet Manure: Nitrogen, Tons		12099	42289
Phosphorus, Tons		1815	6122
Potash, Tons		8642	36731

TABLE 5--MANURE FROM CHICKENS & TURKEYS

Year	Item	Chickens	Turkey Hens	Turkeys Raised
1964		23633646		
1969		24013642		
1972		23648717	480590	4739460
Wet Manure Factor: Lbs. per bird		82.9	365	89.63
Wet Manure Defecated: Tons, 1972		980239	Combined	298910
Nutrients in Wet Manure: Nitrogen, tons		15292		4659
Phosphorus, tons		3921		1195
Potash, tons		3431		1045

Kilograms (kg) = Pounds (lb) x 0.454

Hectare (ha) = Acres (acre) x .4047

Kilograms (kg) = Tons x 907.2

TABLE 6--CROP ACREAGES & FERTILIZER USED--CLASS I-V CENSUS FARMS, 1969

COUNTY, land area, acres (1)	82224464	Number I-V farms	133272
Number of farms	207598	Acres in I-V farms	27449678
Acres in farms	33308065	Cropland I-V farms	20945202
Cropland in farms	24296393	Harvested cropland I-V farms	15529541
Harvested cropland in farms	17117421		

Crops	Crop Acres	Tons of Fertilizer Used: Dry	Tons of Fertilizer Used: Liquid	Tons of Fertilizer Used: Total
CORN	4752367	672758	187349	860107
GRAINS	2863842	294919	12095	307014
Wheat	1168682	152215	8689	160904
Oats	1559708	131093	3120	134213
Barley	49737	5183	153	5336
Rye	46506	3301	77	3378
OTHER FIELD CROPS	3258469	258338	18823	277161
Soybeans	2346991	82587	7831	90418
Potatoes	96133	53198	3015	56213
Sugar beets				
Field beans	99135	597	34	631
HAY OR GRASS SILAGE	3895198	74524	1922	76466
PASTURED CROPLAND	2671806	25640	883	26523
Cropland used for pasture	2351337	21013	744	21757
Improved pasture	320469	4627	139	4766
VEGETABLES, SWEET CORN, MELONS	436589	102630	8081	110711
ORCHARDS	311552	47336	2459	49795
BERRIES	18591	4113	81	4194
NURSERY & GREENHOUSE PRODUCTS	39762	12338	577	12915
OTHER CROPS	14650	1058	132	1190
Total Fertilizer Used, Tons		1494251	232436	1726687
Percent of Fertilizer Used		87	13	100

TABLE 7--FERTILIZER USED IN 1972

Item	Tons
Fertilizer Used on Crops: Solid	2145048
Liquid	599486
Total	2744528
Primary Nutrients in Fertilizer	1312879
Nitrogen	421300
Phosphorus	414034
Potash	477514

TABLE 8--GROUND LIMESTONE EQUIVALENT APPLIED

Year	Tonnage Government Cost/Shared	Tonnage not Government Cost/Shared	Total Tonnage
1972			1459001
Tonnages for Other Recent Years			

TABLE 9--SALTS APPLIED TO FEDERAL, STATE, COUNTY, & MUNICIPAL HIGHWAYS

Year	Tons Purchased Through State	Tons Applied Per "E" Mile
1970-71		
1971-72		
1972-73	1183019	

Total Estimated Tons Applied on All Highways in 1972-73, As Computed 1715856

TABLE 10--SUMMARY OF AGRICULTURAL MATERIALS AND HIGHWAY DE-ICING

Chemicals: Hundredweight Applied on Cropland

	Herbicides	Insecticides	Fungicides	Total
Table 1	270365.9	114589.5	69540.8	454496.2

Manure: Kind of Livestock	Tons of Materials in Wet Manure Defecated: Manure	Nitrogen	Phosphorus	Potash
Swine: Table 2	3785970	19037	5324	14376
Cattle: Table 3	45819157	257381	45960	229804
Sheep: Table 4	864221	12099	1815	8642
Horses: Table 4	6128892	42289	6122	36731
Chickens: Table 5	980239	15292	3921	3431
Turkeys: Table 5	298910	4659	1195	1045
Total from Livestock, Tons	57877389	350757	64337	294029

Fertilizers: Tons of Commercial Fertilizers Applied

Item	Total	Primary Nutrients: Nitrogen	Primary Nutrients: Phosphorus	Primary Nutrients: Potash
Applied on Cropland: Table 7	2744528	421300	414034	477514

Lime: Limestone equivalent purchased or applied, tons: Table 8 1459001

Salts: Applied on all highways, tons: Table 9 1715856

(1) County, land area, acres includes water areas under 40 acres in size.

Agricultural Chemicals

Higher labor and machinery costs have been important factors in encouraging farmers to increase the use of chemicals in the eradication or control of weeds, insects, and diseases. This use of chemicals in agricultural production has been of major concern and on occasion has prompted severe criticism.

One of the major criticisms of chemical use has been the amount of residues remaining after certain chemicals have been used. It is believed now that "carry over" in the use of herbicides and "persistence" in the use of insecticides will be progressively reduced and largely eliminated in the next 5 years. Some of the chemicals now in common use will practically disappear while those with very low if any residues will be emerging.

For the Basin as a whole, there was a total of 20,588,677 kilograms (45,449,620 lbs) of agricultural chemicals. Herbicides accounted for 60 percent, insecticides 25 percent, and fungicides 15 percent of the chemicals used. This amounts to 1.02 kilograms (2.66 lbs) of chemicals applied per acre of harvested cropland. This index was compared to each Lake basin and it was determined that Lake Michigan and Ontario basins were the only ones above the average amount of 1.02 kilograms (2.66 lbs), Lake Michigan using 1.24 kilograms (2.75 lbs) and Ontario 1.38 kilograms (3.05 lbs).

Animal Wastes

It is estimated that the amount of wet manure produced annually in the Great Lakes Basin is approximately 52,389,331 metric tons (57,748,381 tons). Of this amount, cattle produce 79 percent, horses 10 percent, swine 6 percent, sheep 2 percent, and poultry the remaining 3 percent. The amount of primary nutrients in this manure is 1.2 percent of the total, or 640,513 metric tons (706,033 tons).

As an overall average, there are 3057 kilograms (3.37 tons) of manure per harvested acre in the Basin and 37.1 kilograms (82 lbs) of primary nutrients per harvested acre. Lake Ontario basin has the highest average using this index, followed in descending order by the Lake Superior, Michigan, Huron, and Erie basins.

Commercial Fertilizers

For many years it was common to recommend using more fertilizer for better agricultural production. Farmers responded accordingly and have been using more fertilizer. At the same time the amounts of primary nutrients in fertilizer (nitrogen, phosphorus, and potash) have been increasing. In 1955 nutrients represented 33 percent of fertilizer composition; in 1970 they were 46 percent. These changes have further increased the large amounts of nutrients applied to croplands in the basin. A total of 2,489,836 metric tons (2,744,528 tons) of commercial fertilizers were applied to crops in the Great Lakes Basin in 1972. This includes 1,191,041 metric tons (1,312,879 tons) of primary nutrients. The average amount of commercial fertilizer per harvested acre is 145 kilograms (321 lbs), and primary nutrients averaged 69 kilograms (153 lbs) per harvested acre. The Lake basin with the highest average was Lake Huron. Lake Erie was second, followed closely by Lakes Michigan and Ontario. The Lake Superior basin uses the least amount of commercial fertilizers, averaging only 40 percent of the index for fertilizer and 69 percent of the average nutrient amount.

Lime

Lime applied to croplands is important in terms of its water quality impacts due to its effects on the pH level of water and subsequent effects on the waters' acid-base relationships. The possibility of precipitating phosphorous in the water and altering calcium content is also likely.

A total of 1,323,606 metric tons (1,459,001 tons) of limestone was used in the Great Lakes Basin in 1972. The average amount of lime used for the Basin was 31 kilograms per harvested hectare (171 lbs/harvested acre). The Lake Superior basin used the greatest amount, 44.5 kilograms per harvested hectare (243 lbs/harvested acre), with Lake Ontario being second. The Lake Michigan and Erie basins followed closely with the Lake Huron basin using the least amount of lime on croplands, 6.2 kilograms per harvested hectare (34 lbs/harvested acre).

Salts

Due to climatic conditions in the Basin, road de-icing salts are required to keep major roadways clear during the winter. However, the use of salts may have an impact upon ground and surface water areas. Assuming that chlorides are conservative and that ion exchange between chlorides and various soil types are minimal, most of the chlorides will eventually reach ground and surface water areas. Alternative substances have been sought, but none have proven economically feasible. Methods of conserving the amounts used are also being implemented.

The 1972-73 application of road salts totaled 1,556,625 metric tons (1,715,856 tons). The Lake basin using the greatest amount was Lake Erie, which used more than one and one-half times the Basin average (31.3 kilograms or 69.1 lbs per acre of total land area). Lake Ontario basin was second followed closely by the Lake Michigan, Huron, and Superior basins.

MATERIALS USAGE TRENDS

Agricultural Chemicals

It is projected that total amounts of insecticide used may be no larger in 10 years than now. Insecticide use may even decrease as much as 5 to 50 percent in this time period. However, a leveling out is more likely to occur. The use of fungicides will likely increase 10 to 15 percent in the next 10 years. Herbicides are projected to increase the most, approximately 20 to 25 percent. This represents a projected overall increase in combined chemical tonnage of 12 to 18 percent in the next 10 years for the entire Great Lakes Basin.

Future use of agricultural chemicals will also be affected by new research and technology. There will be developments that provide more combination herbicide treatments--an application or two of a combined chemical serving several purposes. Biological methods, or the development of insect populations to counter undesirable insects, have not had much effect to date and probably will not have much more success in the next 10 years.

Animal Wastes

It is projected that manure production from cattle will increase 5 percent in the next 10 years. Beef will be replacing dairy cattle and more young cattle will be retained to be fed out. Horse numbers will be increasing 50 percent and swine numbers 20 percent, increasing manure production proportionately. Turkey increases will not affect manure production nor will sheep decreases, so far as the entire Basin is concerned. It thus appears that total manure production from livestock should be projected to increase 5 to 10 percent in the next 10 years. More significant than the total increase in amounts will be the concentration of livestock production--a big decrease in the number of farm units but a big increase in the amount of livestock kept per unit.

Commercial Fertilizers

Authorities differ as to what would represent reasonable future estimates for commercial fertilizers. Most projections fall within these ranges: phosphorous 0 to 15 percent increase in the next 10 years, potash 10 to 25 percent increase and nitrogen 20 to 35 percent increase. If these percentage figures are applied to the present total amount for nutrients of 1,191,154 metric tons (1,313,000 tons) it would give a range of from 1,313,626 to 1,489,622 metric tons (1,448,000 to 1,642,000 tons) in another 10 years. This represents an overall increase at the rate of about one percent a year.

Lime

Most soil scientists feel that the amount of lime applied from year to year will vary. They project that the annual amount 10 years from now may be about the same as at present.

Salts

In recent years the trend has been to increase the amount of salts used. This is in part due to the fact that the public has looked with favor on what is termed the "bare pavement policy." However, the cost of salt has been increasing substantially and the budgets for road de-icing have tended to remain about the same.

Therefore, it is projected that the amount of salts applied will most likely remain at approximately present rates over the next 10 years. It is felt that some tonnage increases will probably occur, but will be only in proportion to the increase in road mileage.

METHODOLOGY

General

A county summary report has been prepared for all counties where census and other information is reported. This information was available for 187 of the 191 counties in the Great Lakes Basin. The county information was combined into Great Lakes Basin planning subareas and then in turn into the five Lake basin reports which collectively represent the total Basin Summary.

Wide variations exist between the counties, subareas, and Lake basins. For purposes of discussion and in order to facilitate comparisons, it was necessary to develop some indices that would be common to all groupings. It was decided to base the indices on the acres of harvested crops. The acres of harvested crops are the agricultural figures easiest to find and are those reported in most detail. The items considered in this study--chemicals, fertilizers, and lime used and the livestock produced--are all intimately linked to crops harvested. It is acknowledged that where a livestock program makes use of non-cropland for pasture the manure rates per acre of harvested crops will correspondingly overstate the intensity of use. Manure rates shown here are generally well within the limits of intensity developed by the U.S. Environmental Protection Agency. Only one item, road de-icers, is not linked to harvested crop areas. In this study road salt usage was instead linked to total land acres to indicate intensity of use.

Definition of Terms

Following are the terms and indices that will be used in the discussion of materials usage:

1. Pounds of chemicals per harvested crop acre. Pounds of herbicides, insecticides, and fungicides applied per acre of harvested cropland.

2. Chemical use index. This index compares the pounds of chemical used in a subarea or area with the average use in the ovarall Basin. For example, 1.21 kilograms (2.66 pounds) of chemicals were used per harvested crop acre in the entire Great Lakes Basin. However, in the

Lake Ontario basin, 1.38 kilograms (3.05 pounds) were used, or 115 percent of the Basin average. The index of chemicals applied is thus 100 for the entire U.S. Great Lakes Basin and 115 for the Lake Ontario basin.

3. Livestock manure per harvested crop acre. The total tons of all livestock manure defecated, divided by the number of harvested acres.

4. Manure index. The tons of manure per harvested crop acre for a planning subarea or Lake basin compared to the Basin average.

Similar terms were used for the following:

5. Pounds of primary nutrients in manure per harvested crop acre.
6. Index of primary nutrients in manure per harvested crop acre.
7. Pounds of commercial fertilizer per harvested crop acre.
8. Index of commercial fertilizer use per harvested crop acre.
9. Pounds of primary nutrients in fertilizer per harvested crop acre.
10. Index of primary nutrients in fertilizer per harvested crop acre.
11. Pounds of lime applied per harvested crop acre.
12. Index of lime applied per harvested crop acre.
13. Pounds of road de-icers used per acre of total land area.
14. Index of road de-icers used per acre of total land area.

Conversions to the metric system used in this report were:

To Convert From	To	Multiply By
Pounds (lb)	Kilograms (kg)	0.454
Acres (acre)	Hectares (ha)	0.405
Tons (ton)	Kilograms (kg)	907.2
Tons (ton)	Metric Tons	0.907

TABLE 31 Quantitites of Selected Pesticides Used by U.S. Farmers, 1966 and 1971 [1]

	1966	1971			
Pesticide	Total Lbs. (millions)	Total Lbs. (millions)	Percent of Total	Percent Change from 1966	% of Total Used on Crops
Herbicides	116	228	27	+98	99
Insecticides	149	170	21	+14	91
Fungicides (excluding sulfur)	33	41	5	+27	95
Miscellaneous pesticides	56	55	7	-2	85
Sulfur	57	112	13	+96	100
Petroleum	92	222	27	+141	92
TOTAL	503	828	100	+65	92

Kilograms (kg) = Pounds (lb) x 0.454

Agricultural Chemicals

Nationwide Chemical Usage

A national study was conducted by the United States Department of Agriculture in 1971 regarding the quantities of pesticides used in the United States.[1] The study showed a total of 376 million kilograms (828 million pounds) of pesticides used. There were 224 million kilograms (494 million pounds) classified as herbicides, insecticides, fungicides, or miscellaneous pesticides. The other 152 million kilograms (334 million pounds) were sulfur and petroleum. Current pesticide reports will include most sulfur and petroleum in the herbicide, insecticide, and fungicide classes. In addition to the above pesticides used by farmers as shown in the report, there were about 154 million kilograms (339 million pounds) used by the government, industry, and homeowners. Table 31 shows the amounts and percentages of the various pesticides used in the production of crops according to this study.

Herbicides are those pesticides used to destroy or inhibit plant growth, insecticides are those used to control insects, while fungicides are those pesticides used to control various fungi. The U.S.D.A. Study shows that herbicides represented 27 percent, insecticides 21 percent, and fungicides (excluding sulfur) 5 percent for a combined total of 53 percent of the total pesticides used by farmers in 1971.

Great Lakes Basin Chemical Usage

Chemical usage in the 191 Great Lakes Basin counties shows substantial variances from the USDA study. Herbicides are widely used in the Basin in the production of two major crops, corn and soybeans, as well as in production of grains and special crops like field beans and sugar beets. Fungicides are used widely in the production of fruit, vegetable crops, and potatoes, all of which are very important in certain Great Lakes Basin counties. Thus, the total Great Lakes Basin will show herbicides and fungicides in relatively greater use and insecticides in relatively lesser use than the USDA study.

The classification of chemicals used in the U.S. Great Lakes Basin study will be somewhat different from the USDA study. It is calculated, and has been carefully checked with University pesticide authorities, that the combined herbicide, insecticide, and fungicide usage as reported in this study for the Great Lakes Basin represents approximately two-thirds of all the chemicals used by farmers in the 191 counties. Some of the sulfur, petroleum, and miscellaneous pesticides shown separately in the USDA study are included in the herbicide, insecticide, and fungicide groups in this study. Bactericides are a new group of chemicals, not mentioned in the Department of Agriculture study, but now coming into greater importance. These are largely included in the fungicides in this Basin study.

Most discussion of chemical usage by farmers emphasizes herbicides and insecticides. More is generally known about these. Fungicides, and now the bactericides, will be receiving increased attention. In the last decade herbicide usage has increased more rapidly than the other groups of pesticides. Herbicides have largely replaced more expensive mechanical and manual means for controlling weeds and are now used in the production of almost every major crop. Corn accounts for nearly one-half of all herbicide usage. Insecticides and fungicides assume relatively greater significance in the production of the fruit and vegetable crops.

Most published information showing quantities of pesticides used tends to be broad in scope. That is, the quantities shown are totals for a class of chemicals for a specific area or a certain crop. No county figures were available in the 1969 Census of Agriculture or elsewhere, and rates per acre, if shown at all, are difficult to interpret or apply.

The situation is changing as increased attention is being focused on the use of chemicals, including their role in agriculture. One indication of this is the establishement of the National Pesticide Research Center, located at Michigan State University, with a staff of specialists. These specialists and those from other Michigan State University departments, as well as from the Michigan Department of Agriculture, have provided substantial assistance in this study. The following were especially helpful:

Dr. Howard S. Potter, Botany and Plant Pathology

Dr. Alan L. Jones, Botany and Plant Pathology

Dr. Alan R. Putnam, Horticulture

Prof. Leyton V. Nelson, Crop and Soil Science

Dr. Wm. F. Meggitt, Crop and Soil Science

Dr. Donald C. Cress, Entomology

Dr. Donald C. Ramsdell, Botany and Plant Pathology

Dr. Robert F. Ruffel, Entomology

Mr. Frank E. Klackle, Cooperative Extension Service

Mr. Charles A. Hines, State Statistician in Charge, Michigan Department of Agriculture.

Specialists and pesticide authorities from the other Basin states also provided information. These combined efforts resulted in developing Table 32 showing the percent of acres treated, the rates applied per acre, and the major chemicals used. The author, after consulting many reports and interviewing numerous authorities, concluded that the information had sufficient breadth of relevancy to permit use in all of the 191 Basin counties. The acreages of the general farm crops were available, by county, from the reports of the State statistical reporting services.[2] except for pastured cropland for which the 1969 Census figures were the most recent available.[3] For vegetables, acreages were obtainable by State [4a] but not by county except in a few instances.[2a] For fruit crops, production figures were available by state but not by county; however, no acreage figures were shown except in a few isolated state reports.[2c,2d]

Chemical Usage for Vegetables

The total acres of each of the important vegetable crops in each Basin State were multiplied by the chemical application rates per acre and then divided by total acres of all vegetables in that State obtaining a weighted chemical figure per acre for all vegetables in the State. Table 33 illustrates this procedure applied to Wisconsin.

TABLE 32 Cropland Chemical Treatment: Intensity by Crop and Chemical Type

Crop(s)	Type[a]	Percent Acres Treated	Pounds Per Acre	Some of the Major Chemicals Used[b]
Corn	H	90	2.75	Atrazine, Alachlor, 2,4-D Butylate, MCPA
	I	20	1.50	Aldrin, Bux, Chlordane, Carbofuron, Dyfonate
Grain (wheat,oats,barley,rye)	H	60	.50	2,4-D, MCPA, Dinoseb
	I	20	1.00	Carbaryl, Malathion
Soybeans	H	80	2.00	Trifluralin, Dinoseb, Fluorodifen, Chloramben, Linuron, Alachlor, Chlorbromuron
	I	5	1.00	Carbaryl, Malathion
Field beans	H	95	2.50	EPTC, Trifluralin, Chloramben, Fluorodifen
	I	5	1.00	Carbaryl, Malathion, Azinphosmethyl
Sugar beets	H	95	3.00	Pyrazon, TCA Phenmedipham, Dalapon, Endothal
	I	5	1.00	Carbaryl, Parathion, Endosulfan
Hay or grass silage	H	30	1.00	EPTC, MCPA, 2, 4-DB, Simazine
	I	25	1.00	Malathion, Methyoxychlor, Diazinon, Carbaryl, Azinphosmethyl, Methyl Parathion, Imidan
Pastured cropland	H	25	1.00	2, 4-D
	I	25	1.00	Carbaryl
Potatoes	H	90	3.00	Linuron, EPTC, Dinoseb
	I	100	11.50	Phorate, Disyston, Carbaryl, Malathion, Parathion, Azinphosmethyl
	F	100	15.00	Difolatan, Bravo, Dinoseb, Mancozek, Maneb, Zinc, (activated polyethylene thiram disulfide)
Apples	H	70	5.00	Simazine, Paraquat, Terbacil, Dichlobenil, 2,4-D
	I	80	11.75	Guthion, Imidan, Zolone, Sevin, Phosphamidon, Plictran, Omite, Kelthane, Gardona
	F	80	32.00	Benlate, Cyprex, Captan, Difolatan, Polyram, Dikar, Maneb
Sweet cherries	H	75	4.00	Simazine, Paraquat, Dichlobenil
	I	81	5.00	Guthion, Sevin, Imidan, Parathion
	F	81	5.00	Difolatan, Captan, Dodine, Benomyl, Sulfur, Dichlone

[a] H = Herbicides I = Insecticides F = Fungicides

[b] Many chemical scientists believe that "carry over" in the use of herbicides and "persistence" in the use of insecticides may be largely eliminated in the next five years. This means that some chemicals now in common use will practically disappear and the new ones having low, if any, residues will be emerging.

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405
kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

TABLE 32 continued

Crop(s)	Type	Percent Acres Treated	Pounds Per Acre	Some of the Major Chemicals Used
Peaches	H	60	4.00	Simazine, Paraquat, Terbacil, Dichlobenil
	I	74	6.00	Guthion, Sevin, Parathion, Thiodan, Imidan
	F	74	6.00	Benomyl, Sulfur, Dichlone
Pears	H	40	5.00	Simazine, Paraquat, Dichlobenil, Diuron
	I	94	8.00	Guthion, Thiodan, Parathion, Imidan, Sevin, Perthane
	F	94	1.00	Ferbam, Streptomycin, Bordeaux (copper)
Prunes and plums	H	40	3.00	Simazine, Paraquat, Dichlobenil
	I	84	5.00	Guthion, Imidan, Parathion
	F	84	5.00	Benomyl, Dichlone, Sulfur
Strawberries	H	100	10.00	Diphenamid, DCPA, Chloroxuron
	I	90	12.50	Captan, Thiodan
	F	100	10.00	Captan, Benlate
Blueberries	H	85	5.00	Simazine, Diuron, Dichlobenil, Paraquat
	I	85	3.25	Guthion, Malathion
	F	100	41.00	Calcium Cyanamid, DNOSBP
Grapes	H	80	4.00	Simazine, Paraquat, Diuron, Dichlobenil
	I	90	51.00	Folpet, Ferbam, Guthion, Captan, Parathion
	F	100	17.50	Ferbam, Phaltan
Sweet corn	H	100	2.00	Atrazine, Alachlor, Butylate, Cyanazine, 2, 4-D
	I	80	13.50	Parathion, Sevin, Lannate, Gardona, EPM, Dieldrin, Dylox
	F	100	.10	Thiram or Captan
Cantaloupe	H	80	6.00	Naptalam, Bensulide
	I	50	2.00	Methoxychlor, Sevin, Thiodan, Phosphamidon
	F	90	10.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan
Asparagus	H	100	4.00	Simazine, Diuron, Dalapon, 2, 4-D
	I	90	3.00	Sevin, Dieldrin, Methoxychlor, Malathion
	F	50	5.00	Dithiocarbamates, Thiram/Captan

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405

kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

TABLE 32 continued

Crop(s)	Type	Percent Acres Treated	Pounds Per Acre	Some of the Major Chemicals Used
Snap beans	H	90	2.00	EPTC, Trifluralin, Dinoseb, Chloramben
	I	50	6.00	Sevin, Parathion, Diazinon, Dimethoate
	F	75	5.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan
Cabbage	H	100	3.00	Trifluralin, Nitrofen, DCPA
	I	100	4.50	Guthion, Diazinon, Lannate, Monitor, Thiodan, BT
	F	75	7.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan
Carrots	H	100	2.00	Linuron, Nitrofen
	I	100	8.75	Sevin, Parathion, Diazinon
	F	75	10.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan
Cauliflower	H	100	3.00	Trifluralin, Nitrofen
	I	100	4.50	Guthion, Diazinon, Lannate, Monitor, Thiodan, BT
	F	75	7.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan
Cucumbers	H	100	6.00	Naptalam, Bensulide, Chloramban, Dinoseb
	I	50	3.00	Methoxychlor, Sevin, Dieldrin, Parathion
	F	50	10.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan
Lettuce	H	100	6.00	CDEC, Chlorpropham
	I	100	18.00	Sevin, Parathion, Lannate, Thiodan, BT
	F	75	8.00	Dithiocarbamates, Thiram/Captan
Onions	H	100	12.00	CDAA, Chlorpropham, Nitrofen, Chloroxuron
	I	100	6.00	Dasanit, Dyfonate, Diazinon, Parathion, Malathion
	F	75	10.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan
Green peppers	H	100	3.00	Trifluralin, Diphenamid
	I	100	35.00	Sevin, Dibrom, Systox, Dimethoate, Diazinon
	F	50	10.00	Dithiocarbamates, Coppers, Thiram/Captan

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405

kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

TABLE 32 Continued

Crop(s)	Type	Percent Acres Treated	Pounds Per Acre	Some of the Major Chemicals Used
Tomatoes	H	100	3.00	Trifluralin, Diphenamid, Chloramben
	I	25	1.50	Diazinon, Lannate, BT, Guthion, Thiodan
	F	90	10.00	Dithiocarbamates, Copper, Bravo
Celery	H	100	3.00	CDEC, Nitrofen, Prometryne, Linuron
	I	100	18.00	Sevin, Parathion, Systox, Dibrom, Phosdrin
	F	100	16.00	Dithiocarbamates, Copper, Bravo, Dyrene
Green peas	H	100	2.00	Propachlor, Dinoseb, Trifluralin
	I	100	2.00	Parathion, Systox, Dimethoate, Malathion, Diazinon
	F	50	6.00	Dithiocarbamates, Copper, Bravo
Watermelon	H	80	6.00	Naptalam, Bensulide
	I	50	2.00	Methoxychlor, Sevin, Thiodan, Phosphamidon
	F	50	10.00	Dithiocarbamates, Bravo, Coppers, Thiram/Captan

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405
kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

The ratios of vegetable acreages in the Basin States in 1972 compared to 1969 were as follows: New York, 0.85 [59,974 hectares, (148,084 acres) in 1969, 51,150 hectares (126,300 acres) in 1972]; Ohio, 0.88; Indiana, 0.82; Illinois, 0.85; Minnesota, 1.07; Wisconsin, 1.00; Pennsylvania, 0.72; and Michigan, 1.07. The State ratio times the total vegetable acreage, shown in each county in the 1969 Census, times the composite vegetable chemical rates per acre for each State provides the pounds of herbicides, insecticides, and fungicides respectively used on vegetables in each county in 1972.

Chemical Usage for Fruits

A similar procedure to that used with vegetables was followed for fruit. The recent acres of fruit crops by county was available in Michigan, and there was no fruit in the Minnesota counties. In the other States the fruit production figures, stated not in acres but in pounds or tons, were first converted to acres of fruit crops using average yields as the divisors. The chemical usage rates per acre were then applied to these acres to develop composite chemical use rate figures per acre by State for herbicides,

TABLE 33 Wisconsin Vegetable Acres for 1972 and Chemicals Applied

Vegetable	Total Acres	Total Pounds of Chemicals Applied at the Rates Shown in Rate Table[a]		
		Herbicides	Insecticides	Fungicides
Cantaloupe	500	2,400	500	4,500
Green Peas	122,200	244,400	244,400	366,600
Onions	1,500	18,000	9,000	11,250
Cucumbers	9,000	54,000	13,500	45,000
Cabbage	8,600	25,800	38,700	45,150
Sweet Corn	113,500	227,000	1,225,800	11,350
Tomatoes	1,000	3,000	375	9,000
Snap Beans	45,500	81,900	136,500	170,625
Carrots	2,300	4,600	20,125	17,250
Lettuce	900	5,400	17,100	5,400
TOTAL	305,000	666,500	1,706,000	686,125
Rate per acre, lbs.	---	2.185	5.593	2.250

[a] In determining the total amounts of herbicides, insecticides and fungicides used, the rates per acre shown in Table 32 have been applied only to those acres treated, not to total acres. The rates per acre shown in this table can be applied to total acres as these rates have been proportionately reduced.

kilograms (kg) = pounds (lb) X 0.454
hectares (ha) = acres (acre) X 0.405

insecticides, and fungicides used on fruit.

The fruit acres in each county do not experience great fluctuations annually, like vegetable acreages. Therefore, it was assumed that fruit acres per county in 1972 were the same as in 1969. The composite chemical use rates per acre determined above were applied to the county fruit acreage to determine the total quantities of herbicides, insecticides, and fungicides used in a county. The composite figures for the amounts of chemicals used per acre of bearing fruit are shown in Table 34.

TABLE 34 Pounds of Chemicals Applied Per Acres Bearing Fruit

State	Herbicides	Insecticides	Fungicides
New York	4.593	21.109	22.308
Pennsylvania	4.583	16.261	21.860
Illinois	4.800	10.400	25.800
Wisconsin	4.596	9.084	21.327
Ohio	4.663	18.444	25.156
Indiana	4.840	10.962	28.392

Kilograms (kg) = Pounds (lb) x 0.454
Hectares (ha) = Acres x 0.405

Animal Wastes

Information from researchers provided the estimates of the tons of manure defecated from dairy cows, hogs, steers, and sheep of certain weights over a fixed time span. Both United States and State census and crop reporting publications provided information on the number of livestock. Manure defecation factors were then developed for various classes of livestock so that the livestock numbers could be directly converted into tons of manure defecated. After the manure quantities for all kinds of livestock were determined, the quantities of primary nutrients--nitrogen, phosphorous, and potash--in the manure were then derived.

The respective tons of animal manure multiplied by the pounds of each primary nutrient per ton of manure produced from livestock, divided by 2000, gives the tons of primary nutrients. This procedure was simplified by using Table 35.

Commercial Fertilizers

Commercial fertilizer consumption in this study represents all commercial fertilizer materials or products sold or shipped for farm and nonfarm use as fertilizer. Materials used in the manufacturing of registered mixes or for uses other than fertilizer are excluded. The U.S. Department of Agriculture and the statistical reporting services for each of the eight States publish annual summaries containing this information. County fertilizer statistics are more limited.

The fertilizer used on Class I-V farms by counties is available from the 1969 U.S. Census of Agriculture. Fertilizer usage for 1972 was available from both the U.S. Department of Agriculture and the Tennessee Valley Authority. Information on distribution--whether bagged, bulk, or liquid--as well as the primary nutrient tonnages was also available. This made it possible to cal-

TABLE 35 Animal Manure Multipliers

Kind of Livestock	X	Tons of Nutrient Per Ton of Manure	=	Tons of Nutrients
Swine	X	.0050	=	Tons of nitrogen
Swine	X	.0014	=	Tons of phosphorus
Swine	X	.0038	=	Tons of potash
Cattle	X	.0056	=	Tons of nitrogen
Cattle	X	.0010	=	Tons of phosphorus
Cattle	X	.0050	=	Tons of potash
Sheep	X	.0140	=	Tons of nitrogen
Sheep	X	.0021	=	Tons of phosphorus
Sheep	X	.0100	=	Tons of potash
Horses	X	.0069	=	Tons of nitrogen
Horses	X	.0010	=	Tons of phorphorus
Horses	X	.0060	=	Tons of potash
Poultry	X	.0156	=	Tons of nitrogen
Poultry	X	.0040	=	Tons of phorphorus
Poultry	X	.0035	=	Tons of potash

kilograms (kg) = pounds (lb) x 0.454
kilograms (kg) = tons (ton) x 907.2
hectare (ha) = acres (acre) x 0.405
metric tons = tons (ton) x 0.907

culate the tons of fertilizer used, the type (whether liquid or dry), and the amounts of the respective primary nutrients used.

Lime

Lime usage information was not readily available from either the USDA Agricultural Statistics Reports or from most of the State statistical reporting services. The USDA Stabilization and Conservation offices provided infoormation showing the tons that the government cost-shared in each state, but not the total tons applied.

Salts

The Michigan Highway Department provided information from their files showing the tons of road de-icing salts purchased through the Michigan State Highway Department and used in each of the 83 Michigan counties for year 1972-73. It was the opinion of Michigan highway officials that these sales represent 100 percent of the salts used on Federal and State highways in a county, about 50 percent of that used on county roads, and about 30 percent of that used by municipalities within a county. Therefore, to obtain the total amount used, the county purchases were doubled, the municipal purchases were multiplied by 3.33, and these sums were then added to the state purchases. Michigan highway officials believe this represents the most reasonable approach to estimating the total tonnage applied. With these relationships established and the information provided for each county, the total tons applied on all highways in the counties for 1972-73 was established. This figure is shown in each county report along with the quantity of State purchased salts for each county.

It was possible to obtain county information for three years, 1970-71, 1971-72, 1972-73, and to obtain the "Tons of Salts Applied Per 'E' miles of Highway" figures for each of these 3 years. An 'E' mile of highway is equivalent to a mile of two-lane highway.

The procedure used in Michigan to determine the total salt tons applied per county was applied to other counties in the other Basin states and it is believed that the results do represent to a reasonable degree the level of salts applied in the Great Lakes Basin. The index, developed to show the pounds of road salts used in a planning subarea as compared to the U.S. Great Lakes Basin as a whole, used the per acre relationship to the total land area and not the per harvested acre of cropland.

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c. Table 467, Page 318.

d. Table 465, Page 313.

e. Table 478, Page 324. Sheep and Lamb Inventory--Stock Sheep plus Sheep on Feed.

f. Table 477, Page 323.

g. Table 326, Page 326.

h. Table 574, Page 396, and Table 583, Page 405.

i. Table 594, Page 396.

j. Weight per turkey raised was calculated from Table 596, Page 412.

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    a. U.S. Department of Agriculture Statistical Reporting Service and Purdue University, Indiana Crop and Livestock Summary, No. 573, June, 1973.

    b. Michigan Department of Agriculture, Michigan County Livestock Statistics, October, 1973, Page 51.

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13. International Joint Commission, International Reference Group on Great Lakes Pollution from Land Use Activities, Task Group A, Management Programs, Research and Effects of Present Land Use Activities on Water Quality of the Great Lakes, November, 1974.

    A8-9 Loehr, Raymond C. (Cornell University), Water Pollution Problems Associated with Animal Wastes and Intensive Animal Feedlots in the U.S. Portion of the Great Lakes Basin, September, 1974.

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FUTURE TRENDS

The detailed study plan of February 1974 for the International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG) called for an inventory of land use and land use practices with emphasis on certain trends and projections to 1980 and, if possible, to 2020. This section presents what are felt to be the major trends in demographic and economic activities, land uses, specialized land uses, and materials usages for the Great Lakes Basin in the near future.

The general purpose of this section is to provide to the PLUARG effort an indication as to the direction specialized land uses and materials usage may take in the forthcoming decades. The findings are summarized in order to provide the background for determining the magnitude of water quality problems likely to result from these activities in the near future.

In order to provide a general frame of reference to the study, demographic and economic activities based upon the revised OBERS Series C and unpublished Series E projections were utilized. These provided what were felt to be reasonable upper and lower limits within which the population and economic growth in the Great Lakes Basin will fall within the next several decades. In so doing, the demographic and economic projections provide the setting in which subsequent projections of major land uses, specialized land uses, and materials usages were made. The last portion of this section summarizes the methodologies used and the rationale underlying the development of these projections.

SUMMARY AND CONCLUSIONS

The Great Lakes Basin presently contains nearly 15 percent of the nation's population and represents about 4 percent of the total land area. As a result, population density is almost 4 times greater than the national average. Much of this population mass is centered around the Chicago, Detroit, Milwaukee, and Cleveland metropolitan areas. Industrial production is also clustered here, and the Basin employs about one-fourth of the nation's manufacturing work force.

Due to this urban-industrial concentration, both the demographic and economic trends for the Great Lakes Region relate closely to national trends. Based on the OBERS Series E population rate, total U.S. population is projected to increase 46 percent between 1970 and 2020, while that of the Great Lakes will increase about 38 percent. In Series C, the United States population increase will be 98 percent, while that for the Great Lakes will be 95 percent. Projected earnings increases will also be below the national average, reflecting the assumption that regional per capita income will converge toward the national average, thus indicating a relative downward movement for the Great Lakes Region.

In either projection series, changes in specialized land uses and materials usages are not directly dependent upon economic and demographic trends. Specialized land use trends depend, in addition, upon available technologies, land characteristics, and specific economic factors which many times are not related to the larger regional economy. The economic aspects of current agricultural practices will determine to a great extent the trends in the types and levels of materials used throughout the Great Lakes Basin in the next decades.

An important feature of the Great Lakes Basin is its wide diversity of land forms, land uses, and population concentration. Water quality impacts in terms of changing economic and demographic activities, land use, specialized land use practices, and materials usage levels can have moderate to severe local impacts depending upon local conditions.

DEMOGRAPHIC, ECONOMIC, AND LAND USE CHARACTERISTICS

The categories contained in this section include the resident population levels, major economic activity sectors (agriculture, mining, construction, manufacturing, transportation and public utilities, trade, finance, services, and government) and major land use activities (urban land, cropland, pasture, forests, and other lands). The aim is to provide a general picture of what the future may be for these three categories. While not exhaustive in detail, these major categories are seen as forming the general background in which the later discussions of materials usages and specialized land usages take place.

Population

The Great Lakes Basin has grown fairly rapidly in the past, with the total population incrasing about 35 percent between 1950 and 1970 (Table 36). An important factor to consider in regard to population in the Great Lakes Basin is the divergence in population distribution. The Lake Michigan and Lake Erie basins combined contained some 86 percent of the total population of the Great Lakes Basin in 1970, while the Lake Superior basin had only about 2 percent of the total population. The more southerly portions of the Basin are heavily industrialized and contain the majority of the resident population. The population of the northern portions swells during the hunting and vacation seasons.

TABLE 36 Population Levels: 1950-1971[2]

	1950	1962	1969	1970	1971
Great Lakes Basin	21,843,838	26,991,434	29,116,796	29,409,220	29,629,296
Lake Superior	515,329	550,122	537,064	535,542	533,754
Lake Michigan	9,988,365	12,338,385	13,383,122	13,551,843	13,642,678
Lake Huron	844,052	1,082,382	1,218,622	1,239,877	1,256,911
Lake Erie	8,558,663	10,697,821	11,453,257	11,547,714	11,629,261
Lake Ontario	1,937,429	2,322,724	2,524,731	2,534,244	2,566,692

Economics

The Great Lakes Region generally registers a greater economic share (earnings by sector or area population) than the United States as a whole (Table 37). Exceptions are mining and government, where the Great Lakes Region has a lower economic share. Per capita income is greater than that of the United States overall, but is less in the Lake Superior and Lake Huron plan areas. The employment/population ratio for the entire Region, 39 percent, is the same as that for the United States as a whole, but the employment/population ratio for the Lake Superior and Lake Huron plan areas is less than that for the nation.

Agricultural Production

The major agricultural crops (Table 38) grown in the Great Lakes Basin in order of rank are: corn for grain, oats, wheat, and soybeans. The majority of the agricultural production is in the Lake Michigan and Lake Erie basins.

Livestock

The Great Lakes Basin makes a rather small contribution to the total United States livestock production (Table 39). However, portions of the Basin are important dairy and swine producing areas. Lake Michigan and Lake Erie are the major livestock producing areas within the Basin.

TABLE 37 Population, Employment, Personal Income, and Earnings by Industry, 1970 2

	Great Lakes	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Population, midyear	29,409,179	535,542	13,551,843	1,239,877	11,547,714	2,534,203
Per capita income (1967$)	3,777	2,816	3,890	3,245	3,822	3,470
Per capita income Rel. (U.S.=1.00)	1.09	.81	1.12	.785	1.01	1.00
Total employment	11,493,713	182,859	5,446,825	431,129	4,452,410	980,490
Employment/population ratio	.39	.34	.40	.35	.39	.39
Total personal income	111,069,256	1,508,338	52,720,518	4,024,260	44,131,039	8,685,101
Total Earnings	90,696,631	1,148,644	42,865,456	3,217,647	36,594,157	6,870,727
Agriculture, forestry & fisheries	1,121,278	7,963b	483,743	67,144	373,919a	188,509
Agriculture	---	---	---	---	---	---
Forestry and fisheries	---	---	---	---	---	---
Mining	139,401	1,591d	71,141	6,204	40,456c	20,009
Metal	---	---	---	---	---	---
Coal	---	---	---	---	---	---
Crude petroleum & natural gas	---	---	---	---	---	---
Nonmetallic, except fuels	---	---	---	---	---	---
Contract construction	5,392,933	67,111	2,671,845	161,657	2,118,647	373,673
Manufacturing	35,467,905	158,798a	15,741,440	1,533,860	15,512,179	2,521,628
Food & kindred products	---	---	---	---	---	---
Textile mill products	---	---	---	---	---	---
Apparel & other fabric products	---	---	---	---	---	---
Lumber products & furniture	---	---	---	---	---	---
Paper and allied products	---	---	---	---	---	---
Printing and publishing	---	---	---	---	---	---
Chemicals and allied products	---	---	---	---	---	---
Petroleum refining	---	---	---	---	---	---
Primary metals	---	---	---	---	---	---
Fabricated metals & ordnance	---	---	---	---	---	---
Machinery, excluding electrical	---	---	---	---	---	---
Electrical machinery & supplies	---	---	---	---	---	---
Motor vehicles & equipment	---	---	---	---	---	---
Transportation equipment, excluding motor vehicles	---	---	---	---	---	---
Other manufacturing	---	---	---	---	---	---
Trans., comm. & public utilities	5,961,189	94,868a	3,035,695	135,616	2,287,177	407,833
Wholesale and retail trade	14,785,401	172,766	7,404,823	475,750	5,706,428	1,025,634
Finance, insurance & real estate	3,909,791	29,788	2,137,872	70,200	1,422,203	249,728
Services	12,379,947	142,498	6,112,647	331,907	4,856,711	936,184
Government	11,222,068	304,410	5,153,896	419,235	4,228,387	1,116,140
Federal government	1,924,828	45,334	968,460	37,868	728,624	144,542
State and local government	8,643,999	182,869	3,838,565	343,661	3,361,169	917,735
Armed forces	653,032	76,207	346,871	37,705	138,587	53,662

*Employment is for 1960
a--represents 80.0 to 99.9 percent of the true value
b--represents 60.0 to 79.9 percent of the true value
c--represents 40.0 to 59.9 percent of the true value
d--represents 20.0 to 39.9 percent of the true value
e--represents zero to 19.9 percent of the true value
s--too small to project

TABLE 38 Agricultural Production, Great Lakes Basin, Current Normal Average (1958-1972)[2]
(in thousands)

Crop	Unit	Great Lakes	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Wheat	Bu.	68,514	51	24,336	11,921	27,829	4,377
Oats	Bu.	102,135	1,320	56,711	6,196	23,317	14,591
Rye	Bu.	1,624	4	673	207	510	230
Barley	Bu.	2,089	25	1,432	218	253	161
Corn for Grain	Bu.	349,759	8	184,488	19,721	134,718	10,824
Corn Silage	Ton	14,962	26	7,858	1,142	2,942	2,994
Soybeans	Bu.	65,426	-	17,592	1,981	45,798	55
Dry E.D. Beans	Cwt.	7,625	-	729	4,524	470	1,902
Sugar Beets	Ton	1,515	-	31	995	489	-
Potatoes	Cwt.	20,226	553	9,729	2,302	3,274	4,368
Fruits	Ton	1,095	4	618	14	255	204
Comm. Vegetables	Cwt.	46,363	66	22,051	2,290	10,867	11,089
Alfalfa Hay*	Ton	8,991	85	5,129	770	1,411	1,596
Clover & Timothy Hay*	Ton	3,070	275	767	97	908	1,023
Cropland Pasture*	Ton	699	-	594	-	-	105
Improved Pasture*	Ton	-	-	-	-	-	-
Improvable Pasture*	Ton	-	-	-	-	-	-
N. Improv. Pasture*	Ton	-	-	-	-	-	-

*Alfalfa hay equivalents (tons).

kilograms (kg) = tons (ton) x 907.2
kilograms (kg) = hundred weights (cwt) x 202.5
metric tons = tons (ton) x 0.907
hectoliters (hl) = bushels (bu) x 0.352

TABLE 39 Livestock Production 1972[3]

Livestock	Great Lakes Basin	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Swine	2,552,259	5,363	1,343,854	94,410	1,063,596	45,036
Cows & Heifers Calved	2,200,115	49,500	1,044,751	151,500	491,857	462,507
Heifers, Steers, Bulls, Calves	2,601,932	58,900	1,409,137	249,900	550,521	333,474
Sheep & Lambs	536,783	5,437	188,177	28,600	254,135	60,434
Horses & Ponies	479,569	10,014	212,129	40,265	148,638	68,523
Chickens	23,648,717	310,900	9,655,948	1,721,300	8,807,844	3,152,725
Turkey Hens	480,090	800	231,420	---	234,960	12,910
Turkeys Raised	4,739,460	8,000	2,304,260	---	2,298,100	129,100

Land Use

The total land area of the Great Lakes Basin encompassed 33,850,000 hectares (83,580,000 acres). The five Lake basins show great diversity in land use (Table 40). Urban land as a percent of total land use in the individual basins ranges from 3 to 15 percent, cropland use ranges from 4 to 55 percent, and forest lands range from 19 to 90 percent. These variations in land use tend to reflect the population distribution of the Basin. The more southern portions of the Basin with their greater population levels contain more of the urban land area. The forested northern portions provide a favorable asset for tourism and recreational pursuits.

Land use figures in this section are taken from the Great Lakes Basin Framework Study, Appendix 13, "Land Use and Management", to be consistent with the trends used, from the same source.

Currently (1970) in the Great Lakes Basin, 64 percent of the cultivated agricultural lands are in cropland, with row crops and hay and pasture accounting for the major uses. Permanent pasture accounts for 11 percent and idle cropland for 25 percent of the total agricultural land.

The Lake Michigan basin contains 45 percent of all the agricultural acreage in the Great Lakes Basin (Table 41). The only category in which the acreage in another basin exceeds that in Lake Michigan is row crops in Lake Erie. Over one-half of the agricultural land in the Lake Superior basin and almost one-half the agricultural land in the Lake Ontario basin is in idled cropland or permanent pasture.

TABLE 40 Present Land Use: 1966-67 Base (Area measured by county boundaries, 1,000 acres)[4]

	Total Land Area	Urban Buildup	% Land Area	Crop Land	% Land Area	Pasture Range	% Land Area	Forest Land	% Land Area	Other	% Land Area
Great Lakes Basin	83,579.7	6,987.7	8.4	28,609.0	34.3	3,505.8	4.0	39,624.5	47.4	4,852.5	5.8
Lake Superior	15,915.3	422.3	3	692.9	4	165.3	1	14,264.5	90	370.3	2
Lake Michigan	32,272.4	2,907.8	9	13,016.1	40	1,405.3	5	12,596	39	2,347	7
Lake Huron	8,441.9	568.6	7	2,901.2	34	358.8	4	4,109	49	504.3	6
Lake Erie	15,678.4	2,421.3	5	8,550.7	55	715.4	5	3,022.4	19	968.6	6
Lake Ontario	11,271.7	667.7	6	3,448.1	30	861	8	5,632.6	50	662.3	6

In terms of crops grown, the major harvested acreage is used for grain corn, alfalfa hay, and soybeans (Table 42). The Great Lakes Basin produces a large portion of the total United States dried edible beans, primarily in the Lake Huron basin. The Lake Michigan basin generally leads the other four Lake basins in the amount of acreage devoted to each crop, with the exception of wheat, soybeans, and dried edible beans.

ALTERNATIVE FUTURES

Any specific set of economic, demographic, and land use projections is subject to considerable conjecture. Therefore, at least two sets of alternative futures are considered. The projections in this report are based on the 1972 revised OBERS Series C and Series E national economic and demographic projections. Differences between the two series in figures for population, personal income, and cropland harvested are caused primarily by different population growth rate assumptions. However, the following additional changes also contribute to differences in the two projections.

(1) The hours worked per year are projected to decline at the rate of 0.35 percent per year in the Series E data, while Series C assumed a 0.25 percent rate.

(2) The projected rate of increase in product per man hour in the private economy is lowered from 3.0 percent in the Series C projections to 2.9 percent in the Series E projections.

TABLE 41 Agricultural Acreage Under Cultivation by Categories [4]
Current Normal Average (1958-1972) (1000 acres)

	Great Lakes Basin	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Specialty Crops	1,397.1	9.4	701.1	115	337.3	234.3
Raw Crops	8,951.1	3.4	3,721.3	983.7	3,785.7	457
Small Grains	3,599.3	46	1,596.9	379.5	1,178.5	398.4
Hay & Pasture	6,714.0	333.8	3,078.2	560.9	1,435.1	1,306
Total Cropland	20,661.5	392.6	9,097.5	2,039.1	6,736.6	2,395.7
Idled Cropland	7,947.4	300.3	3,918.6	862.1	1,814	1,052.4
Permanent Pasture	3,505.6	165	1,405.3	358.8	715.5	861
TOTAL	32,112.8	856.2	14,421.4	3,260	9,266.1	4,309.1

hectares (ha) = acres (acre) x 0.405

(3) Earning per worker in the individual industries at the national level are projected to converge towards the all-industry rate more slowly in the Series E projections than in the Series C projections.

(4) Income data for 1970 and 1971 and total employment data for 1970 were included in the Series E projections. This additional information was not available for the Series C projections, and has caused some changes in certain area projections.

(5) On the basis of the President's 1974 budget message to Congress, a smaller military establishment has been assumed in Series E.

The differences in population growth between the Series C and Series E projections lies mainly in the total fertility rates per 1,000 women assumed to be attained by the year 2005. For Series C the total fertility rates per 1,000 women is assumed to be 2,800 by the year 2005, and for the Series E projections the assumed fertility rates per 1,000 women are 2,100 for the year 2005. The Series E projections move more quickly towards a near-zero population growth level. Due to the present age structure of the population, a near-zero population growth is not reached until the middle of the 21st century. While neither projection trend is an accurate picture of the eventual growth rate in the Great Lakes Basin by the year 2020, the probable growth rate will likely fall somewhere in between these ranges.

Demographic Trends

Population projections for the Great Lakes Basin as a whole range from a low of 31,913,900 persons (Series E) to 34,075,368 persons (Series C) by 1980 (Table 43). By 2020 the population level will grow between 1.4 times according to Series E projections and 1.95 times according to the Series C projections, based upon 1970 levels (Figure 20). The population increase in the Great Lakes Basin is expected to be somewhat smaller than the national average for both projections.

TABLE 42 Agricultural Land Use, Great Lakes Study Area, Current Normal Average (1958-1972)[4]

Crop	Great Lakes		Lake Superior		Lake Michigan		Lake Huron		Lake Erie		Lake Ontario	
	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares
Wheat	1,756.3	710.7	1.6	0.6	612.9	247.9	256.5	103.8	765.0	309.6	120.3	48.8
Oats	1,695.9	686.4	38.8	15.7	897.5	363.2	109.2	44.3	388.6	157.3	261.8	106.0
Rye	59.8	24.1	0.2	*	27.8	11.2	7.7	3.1	17.5	7.1	6.6	2.7
Barley	44.7	18.1	0.9	0.4	29.8	12.1	4.7	1.9	6.0	2.4	3.3	1.3
Misc. Small Grains	42.6	17.3	4.5	1.8	28.9	11.7	1.4	0.6	1.4	0.6	6.4	2.6
Corn for Grain	4,369.5	1,768.2	0.2	*	2,276.3	921.2	284.7	115.3	1,657.5	670.7	150.8	61.0
Corn Silage	1,220.8	494.1	3.2	1.3	653.4	264.4	107.3	43.5	240.4	97.3	216.5	87.6
Soybean	2,605.5	1,054.2	---	---	671.4	271.7	96.8	39.1	1,835.1	742.6	2.2	0.8
Dry E.D. Beans	755.3	305.6	---	---	120.2	48.6	494.9	200.3	52.7	21.3	87.5	35.4
Sugar Beets	124.8	50.5	---	---	0.7	0.3	71.0	28.7	53.1	21.5	0	0
Potatoes	151.7	61.4	5.9	2.4	72.1	29.3	19.5	7.9	30.8	12.4	23.4	9.4
Fruits	600.1	243.2	2.8	1.1	367.8	149.2	13.9	5.7	114.1	46.2	101.5	41.0
Comm. Vegetables	520.5	210.6	0.7	0.3	260.5	105.4	10.6	4.2	139.3	56.4	109.4	44.3
Comm. Sod	52.7	21.4	0.1	*	28.7	11.7	2.7	1.1	20.7	8.4	0.5	0.2
Alfalfa Hay	3,699.1	1,497.0	59.9	24.2	2,030.8	821.9	371.9	150.6	609.4	246.6	627.1	253.7
Clover & Timothy Hay	1,921.1	777.3	203.0	82.1	452.6	183.1	69.2	28.0	624.5	252.7	571.8	231.4
Cropland Pasture	1,041.6	421.5	71.1	28.8	565.3	228.7	118.1	47.8	180,5	73.1	106.6	43.1
Idle Cropland	7,947.4	3,216.2	300.3	121.5	3,918.6	1,585.8	862.1	348.8	1,814.0	734.2	1,052.4	425.9
Total Cropland	28,609.2	11,578.2	692.9	280.5	13,016.1	5,268.0	2,901.2	1,174.1	8,550.6	3,460.4	3,448.0	1,395.2
Improved Pasture	934.2	378.1	33.3	13.5	385.2	155.9	67.9	27.4	242.0	98.0	205.8	83.3
Improvable Pasture	2,245.7	908.8	103.6	41.9	936.0	378.8	290.9	117.7	455.3	184.2	459.9	186.2
N. Improv. Pasture	324.6	131.3	28.5	11.5	83.8	33.9	---	---	17.0	6.9	195.3	79.0
Total Pasture	3,504.4	1,418.4	165.3	66.9	1,405.0	568.7	358.8	145.2	714.3	289.1	861.0	348.5
Total Ag. Land[a]	32,113.6	12,996.1	858.2	347.3	14,421.4	5,836.3	3,260.0	1,319.3	9,266.1	3,749.5	4,309.1	1,743.7

[a] Totals may not add due to rounding.

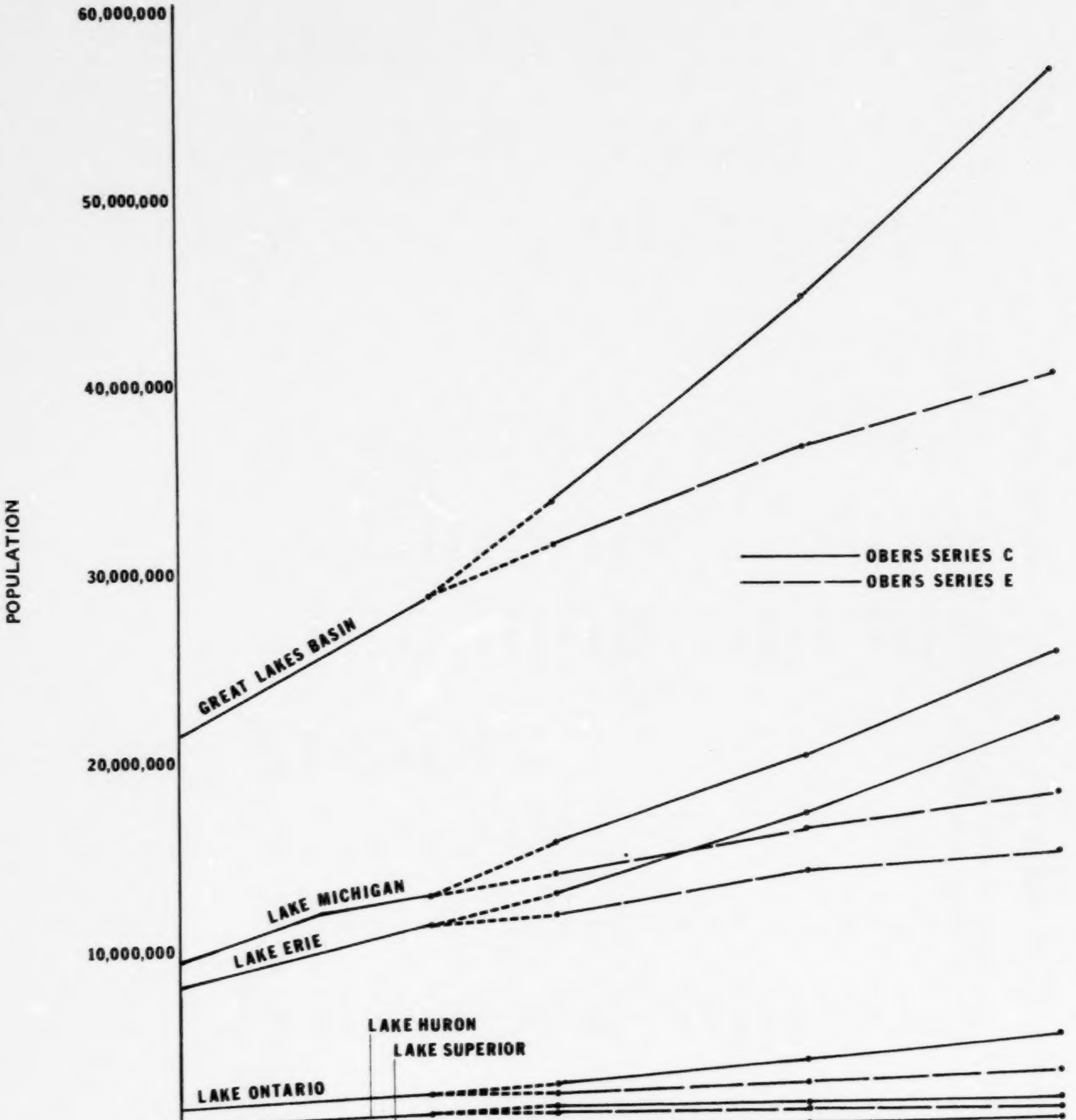

FIGURE 20 Population Levels 1950 to 2020 [1,2]

TABLE 43 Projected Population Growth: Great Lakes Basin[1,2]

	1970	1980	2000	2020
Great Lakes Basin				
Series C	29,409,220	34,075,368	44,515,009	57,404,959
Series E	29,409,220	31,913,900	36,745,700	40,615,500
Lake Superior basin				
Series C	535,542	590,000	717,800	884,800
Series E	535,542	531,500	528,200	532,200
Lake Michigan basin	13,551,843	15,592,600	20,145,900	25,762,200
Series C	13,551,843	14,709,300	16,862,500	18,630,000
Series E				
Lake Huron basin				
Series C	1,239,877	1,456,900	1,952,300	2,557,800
Series E	1,239,877	1,390,900	1,678,500	1,891,800
Lake Erie basin				
Series C	11,547,714	13,424,200	17,548,400	22,577,400
Series E	11,547,714	12,442,500	14,262,300	15,679,100
Lake Ontario basin				
Series C	2,534,244	3,011,668	4,150,609	5,622,759
Series E	2,534,244	2,839,700	3,414,200	3,882,400

There will be some differences in the growth rates of the individual Lake basins. The Lake Superior basin will grow the least in both projections declining slightly in Series E and increasing 65 percent in Series C. The Lake Huron basin is projected to grow most--between 53 and 87 percent by 2020 for Series E and C respectively.

Economic Trends

Per capita income levels are about the same in both projections (Tables 44,45). The per capita income level for the Great Lakes Region will remain slightly above that of the United States as a whole, but will decline slightly towards the United States average. The relationship of income to the national average is in part dependent upon productivity and overall economic growth, as well as per capita consumption and demand.

Although total employment figures differ in the two projections based upon population level expectations, the employment to population ratio shows only slight differences. The Series C projections forecast the employment to population ratio increasing slowly from the 1970 level of 39 percent to 42 percent by 2020, while Series E projects a growth from 39 to 45 percent in the same period. In all Lake basins, the acceleration of the employment to

TABLE 44 Population, Employment, Personal Income, and Earnings by Industry; 1970, 1980, 2000 and 2020. Series E Great Lakes Basin 2

	1970	1980	2000	2020
Population, midyear	29,409,179	31,913,900	36,745,700	40,615,300
Per capita income (1967 dollars)	3,777	5,200	8,800	14,000
Per capita income Rel. (U.S.=1.00)	1.09	1.10	1.09	1.06
Total employment	11,493,713	13,984,900	16,760,400	18,281,700
Employment/population ratio	.39	.44	.46	.45
		1,000	(1967 dollars)	
Total personal income	111,069,256	166,041,800	323,044,000	567,757,500
Total earnings	90,696,631	134,130,900	254,709,000	447,722,600
Agriculture, forestry & fisheries	1,121,278	1,266,700	1,485,600	1,860,900
Agriculture	—	1,256,200	1,470,700	1,839,300
Forestry and fisheries	—	6,700	9,900	14,200
Mining	139,401	409,600	520,800	687,200
Metal	—	186,700	220,500	278,800
Coal	—	3,700	6,000	9,100
Crude petroleum & natural gas	—	37,100	42,700	51,400
Nonmetallic, except fuels	—	180,000	249,000	344,800
Contract construction	5,392,933	8,112,700	14,622,400	24,242,200
Manufacturing	35,467,905	49,064,300	82,875,100	133,342,500
Food & kindred products	—	2,557,300	3,443,700	4,681,300
Textile mill products	—	159,700	197,900	259,400
Apparel & other fabric products	—	588,000	834,900	1,196,300
Lumber products & furniture	—	967,500	1,474,000	2,190,900
Paper and allied products	—	1,491,200	2,620,800	4,279,200
Printing and publishing	—	2,611,600	4,837,900	8,161,800
Chemicals and allied products	—	2,475,900	4,773,100	8,394,800
Petroleum refining	—	465,500	727,200	1,080,800
Primary metals	—	4,386,900	5,794,900	7,689,600
Fabricated metals & ordnance	—	5,175,000	8,872,800	14,252,400
Machinery, excluding electrical	—	6,587,700	9,979,800	14,964,600
Electrical machinery & supplies	—	4,993,200	10,134,400	18,437,200
Motor vehicles & equipment	—	9,717,000	17,055,600	27,800,400
Transportation equip., excl. mtr. vehs	—	963,300	1,431,200	2,044,300
Other manufacturing	—	5,911,100	10,681,300	17,892,500
Trans., comm. & public utilities	5,961,189	8,546,000	15,803,900	27,202,400
Wholesale and retail trade	14,785,401	20,821,800	36,567,500	60,179,288
Finance, insurance & real estate	3,909,791	6,553,900	14,029,400	26,209,700
Services	12,379,947	21,954,400	51,247,000	102,435,700
Government	11,222,068	17,394,100	37,550,300	71,455,100
Federal government	1,924,828	2,806,200	5,710,900	11,272,800
State and local government	8,643,999	13,950,400	30,813,100	58,518,800
Armed forces	653,032	636,600	1,024,500	1,662,000

*Employment is for 1960.
a-represents 80.0 to 99.9 percent of the true value
b-represents 60.0 to 79.9 percent of the true value
c-represents 40.0 to 59.9 percent of the true value
d-represents 20.0 to 39.9 percent of the true value
e-represents zero to 19.9 percent of the true value
s-too small to project

TABLE 45 Population, Employment, Personal Income, and Earnings by Industry; 1970, 1980, 2000 and 2020. Series C Great Lakes Basin [1]

	1970	1980	2000	2020
Population, midyear	29,409,179	34,075,368	44,515,009	57,404,959
Per capita income (1967 dollars)	3,777	5,395	9,060	15,186
Per capita income Rel. (U.S.=1.00)	1.09	1.13	1.09	1.06
Total employment	11,493,713	13,817,556	18,349,514	23,848,907
Employment/population ratio	.39	.42	.42	.42
		1,000 (1967 dollars)		
Total personal income	111,069,256	178,453,995	397,466,425	871,750,660
Total earnings	90,696,631	143,638,500	311,814,000	670,330,000
Agriculture, forestry & fisheries	1,121,278	1,292,000	1,639,000	2,856,900
Agriculture	—	1,279,500	1,619,000	2,825,400
Forestry and fisheries	—	12,400	19,700	31,300
Mining	139,401	486,100	794,600	1,340,200
Metal	—	217,000	340,400	544,600
Coal	—	10,200	14,600	19,900
Crude petroleum & natural gas	—	42,600	54,700	68,600
Nonmetallic, except fuels	—	216,200	384,700	706,800
Contract construction	5,392,933	8,830,000	18,928,300	40,100,810
Manufacturing	35,467,905	54,477,000	106,400,000	210,968,400
Food & kindred products	—	2,729,000	4,229,000	6,742,000
Textile mill products	—	194,800	301,000	492,000
Apparel & other fabric products	—	718,700	1,260,500	2,290,000
Lumber products & furniture	—	1,151,000	1,971,000	3,490,000
Paper and allied products	—	1,627,000	3,401,000	7,135,000
Printing and publishing	—	2,696,000	5,489,000	11,303,000
Chemicals and allied products	—	2,612,000	5,542,500	11,677,900
Petroleum refining	—	429,000	706,100	1,163,900
Primary metals	—	5,160,000	7,970,000	12,414,300
Fabricated metals & ordnance	—	6,063,000	12,529,000	25,775,000
Machinery, excluding electrical	—	8,327,000	16,630,000	33,470,000
Electrical machinery & supplies	—	5,344,000	12,161,900	26,741,000
Motor vehicles & equipment	—	9,564,000	17,808,000	33,941,300
Transportation equipment, excluding motor vehicles	—	1,388,100	2,775,600	5,624,000
Other manufacturing	—	6,462,000	13,625,900	28,677,000
Trans., comm. & public utilities	5,961,189	8,483,000	16,756,300	33,771,000
Wholesale and retail trade	14,785,401	23,742,000	52,303,000	114,081,000
Finance, insurance & real estate	3,909,791	6,201,300	13,390,000	28,825,000
Services	12,379,947	21,544,000	53,743,800	125,287,000
Government	11,222,068	18,583,000	47,860,000	113,100,400
Federal government	1,924,828	—	—	—
State and local government	8,643,999	—	—	—
Armed forces	653,032	761,000	1,274,500	2,129,000

population ratio is greater in the Series E projections than in the Series C projections. With respect to earnings by sector (Figure 21), agriculture accounts for well less than one percent of total earnings in both projections. Earnings in mining also account for well below one percent of total earnings. Construction earnings differ slightly in the two projections--about 5.9 percent of the total in Series C and 5.4 percent in Series E. The manufacturing sector has the highest percent of total earnings in both projections by 2020--29.8 percent in Series E and 31.5 percent in Series C. The sector comprised of transportation, communications, and public utilities will contribute 5 to 6 percent of the total earnings in 2020. The projections for the wholesale and retail trade sectors will vary by four percent by 2020 and will amount to 13 percent of the total earnings in Series E projections or 17 percent of total earnings in the Series C projections. The financial sector will account for between 4 and 6 percent of total earnings by 2020. Earnings in the service sector will be between 19 percent and 23 percent of the total earnings in 2020. The government sector will have between 16 and 17 percent of the total earnings by 2020.

The major changes from the 1970 level contained in these projections are in manufacturing and services. Manufacturing will decline from 39 percent of the total earnings in 1970 to between 29.8 and 31.5 percent in 2020. Earnings in the service sector will increase from about 14 percent of the total to between 19 and 23 percent. Earnings in the government sector as a percentage of the total are projected to increase as well, from 12 percent in 1970 to 16-17 percent in 2020. As can be seen, earnings by sector will be relatively stable throughout the period from 1970 to 2020.

Total earnings will vary greatly by Lake basin (Figure 22). By 2020, Lake Michigan and Lake Erie basins will have roughly comparable total earnings, while earnings in the Lake Superior basin will lie well below those of the other Lake basins. The Lake Superior basin also shows the greatest projected increase in earnings and the greatest difference between Series C and Series E projections.

Agricultural Trends

The agricultural sector of the Great Lakes Region is quite diverse. The patterns of agricultural enterprise projected for the future will reflect not only the Regions's comparative advantage in production, but also its proximity to large urban markets. Fruit and commercial vegetable production will remain important in areas of Wisconsin, Michigan, Ohio, and New York due to their proximity to urban centers. The southern portion of the Region, with its heavy loam soil, will remain an important feed grain area.

Oats, grain corn, soybeans, and commercial vegetables will continue to be the major crops in terms of production in the Great Lakes Region based on both the Series C and E estimates for the time period 1970 to 2020 (Tables 46, 47).

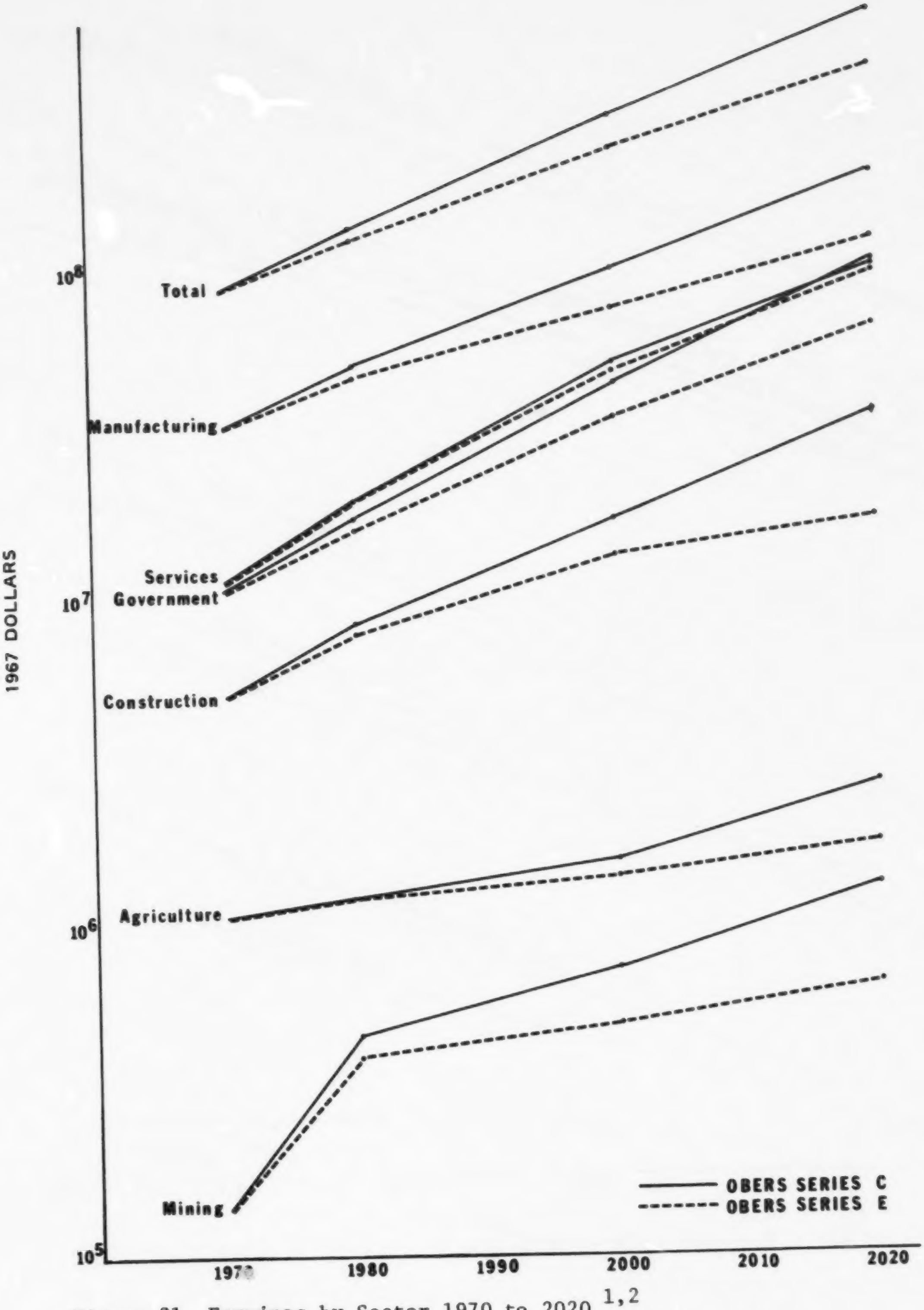

Figure 21 Earnings by Sector 1970 to 2020 [1,2]

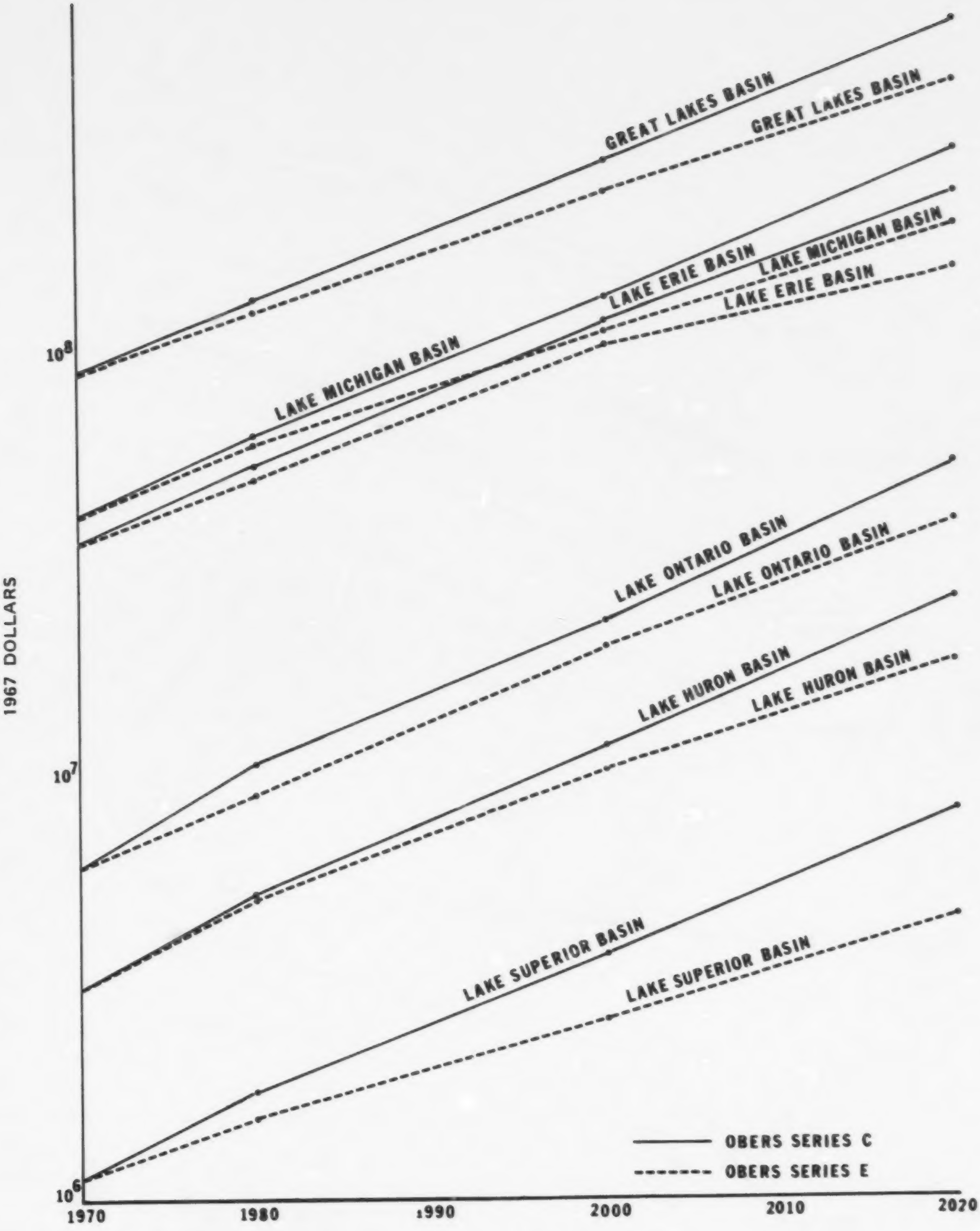

Figure 22 Total Earnings 1970 to 2020 1,2

TABLE 46 Crop Production, Great Lakes Basin, 1980, 2000, and 2020.[2]
Series E (1000 units)

Crop	Units	Current Normal	1980	2000	2020
			Thousands		
Wheat	Bu.	68,514	66,170	57,850	45,669
Oats	Do.	102,135	111,394	132,665	142,914
Rye	Do.	1,624	1,603	1,629	1,455
Barley	Do.	2,089	1,491	610	343
Corn for grain	Do.	349,759	488,692	705,270	759,048
Corn silage	Ton	14,962	16,476	19,018	19,509
Soybeans	Bu.	65,426	105,472	184,677	231,702
Dry E.D. beans	Cwt.	7,625	8,675	10,433	11,456
Sugar beets	Ton	1,515	2,877	3,990	5,018
Potatoes	Cwt.	20,226	22,406	25,251	26,227
Fruits	Ton	1,095	1,332	1,490	1,673
Comm. vegetables	Cwt.	46,363	61,684	71,233	183,773
Alfalfa hay*	Ton	8,991	9,043	9,477	9,493
Clover & Timothy hay*	Ton	3,070	3,072	3,057	2,874
Cropland pasture*	Ton	699	1,457	1,627	2,168
Improved pasture*	Ton		1,777	2,284	2,544
Improvable pasture*	Ton		2,455	2,850	3,148
N. Improv. pasture*	Ton		194	213	241

*Alfalfa hay equivalents (tons)
** Less than 500 units
kilograms (kg) = tons (ton) X 907.2
metric tons = tons (ton) X 0.907
kilograms (kg) = hundred weight (cwt) X 202.5
hectoliters (h) = bushels (bu) X 0.352

All crops will increase in production throughout the time period in the Series C projections. Crops that will decrease throughout the time period in Series E are wheat, barley, clover, and timothy hay. In addition, rye production will decline between 2000 and 2020.

The major differences between the two projections are wheat, grain corn, soybeans, and commercial vegetables. Wheat is projected to more than double in Series C, but will decline by one-third in the Series E projections. For the other crops--grain corn, soybeans, and commercial vegetables--the increase in production is greater in the Series E projections. Grain corn will in-

TABLE 47 Crop Production Projections for 1980, 2000, 2020[4]
Series C (1000 units) Great Lakes Basin

Crop	Units	Current Normal	1980	2000	2020
Wheat	Bu.	65,142	96,400	111,800	133,600
Oats	Bu.	100,135	154,375	143,500	105,813
Rye	Bu.	1,739	1,902	2,516	3,386
Barley	Bu.	2,089	5,917	6,042	5,625
Corn for Grain	Bu.	349,759	383,357	506,679	675,071
Corn Silage	Ton	14,962	16,374	21,904	28,912
Soybeans	Bu.	65,426	107,440	135,048	174,176
Dry Edible Beans	CWT	6,352	11,376	15,029	20,171
Sugar Beets	Bu.	1,599	3,218	5,280	8,178
Potatoes	CWT	17,987	21,180	28,988	40,404
Fruits	Ton	1,104	1,458	2,097	2,996
Comm. Vegetables	CWT	46,093	72,380	99,295	137,171
Alfalfa Hay	Ton	8,991	9,763	10,084	10,982
Clover & Tim. Hay	Ton	3,070	3,385	3,099	3,018
Cropland Pasture	*	NA	1,446	1,653	2,289
Improved Pasture	*	--	1,922	2,212	2,402
Not Improved Pasture	*	--	184	207	231

*Alfalfa hay equivalents (tons)

Kilograms (kg) = Tons x 907.2
Metric Ton = Tons x 0.907
Kilograms (kg) = Hundredweight (cwt) x 202.5
Hecto Liter (h) = Bushels (bu) x 0.352

crease in production 93 percent in Series C and 117 percent in Series E. Soybeans will increase between 166 percent in Series C and 254 percent in Series E. Commercial vegetables show the widest range between projections--a 197 percent increase in Series E and a 324 percent increase in Series E.

Livestock Trends

Tables 48 and 49 present the livestock production for eight livestock products from OBERS Series C and E data. For Series C all livestock production is projected to increase throughout the time period 1980-2020. In contrast, Series E projects a decline in production of one-half of the livestock varieties--declines are foreseen for lamb, chicken, broilers, and eggs. In the Series E projections, the increases foreseen for the other types of livestock are not as great as the increases in Series C.

TABLE 48 Projected Livestock Production 1980, 2000, 2020;[2]
Series E, Great Lakes Basin, (1,000 units)

Livestock Production	Units	1960	1980	2000	2020
Beef and Veal	Lb.	1,393,500	1,378,723.4	1,480,777.4	1,588,685.6
Pork	Lb.	931,500	904,518.3	1,005,847.9	1,108,847.9
Lamb and Mutton	Lb.	54,500	11,938.2	7,517.8	4,775.4
Chicken	Lb.	82,400	60,633.6	45,985.9	34,305.2
Broilers	Lb.	93,000	32,294.8	20,489.6	14,387.7
Turkeys	Lb.	72,200	112,444.6	165,775.0	197,193.1
Eggs	Doz.	391,300	341,791.8	313,428.8	278,399.5
Milk	Lb.	20,364,800	20,533,399.1	20,886,854.2	20,977,916.9

Kilograms (kg) = Pounds (lb) x 0.454

With the Series C projections, each planning subarea's share of the Great Lakes total projected output remain constant. The Lake Superior basin has less than one or two percent of the total production of any of the eight types of livestock. The majority of the livestock production is in the Lake Michigan basin. This area leads in the production of every type of livestock and has at least one-third of the Great Lakes total in each category in 1980. By 2020 it contains at least 30 percent of the Great Lakes total in each category of livestock. Major shifts in production in the Series E projections are an increasing concentration of chickens in the Lake Ontario basin, and an increasing concentration of broilers in the Lake Michigan basin, which will have over 75 percent of the total broilers by 2020.

Land Use Trends

The projection in both Series C and E is that urban land will increase and will expand into area now occupied by other land uses (Table 50). The primary impact in the Basin as a whole will be on cropland and pasture land. Urban land will expand between 32 and 72 percent between the base year and the year 2020. Cropland will decrease 5 to 11 percent while pasture land will decrease 4 to 8 percent. In the Series C projections, the greatest increases in urban land area will be in the Lake Michigan and the Lake Erie areas. In the Series E projections, the greatest increases will be in the Lake Ontario and the Lake Erie areas.

Another land use that can be of importance in determining water quality relationships is land used for extractive minerals (Table 51). Land needs for this purpose are expected to increase almost 400 percent by 2020. The primary growth will be for iron ore in the Lake Superior basin. This type of mining can have important water quality implications and is expected to take over 4 times the land area in 2020 as it does currently.

TABLE 49 Projected Livestock Production 1980, 2000, 2020;[5] Series C, Great Lakes Basin, (1,000 units)

Livestock Production	Units	1960	1980	2000	2020
Beef and Veal	Lb.	1,393,500	1,888,400	2,649,900	3,722,800
Pork	Lb.	931,500	1,277,100	1,762,900	2,446,300
Lamb and Mutton	Lb.	54,500	52,800	73,800	103,600
Chicken	Lb.	82,400	85,500	117,700	162,900
Broilers	Lb.	93,000	85,600	116,800	160,800
Turkeys	Lb.	76,200	154,900	212,700	294,100
Eggs	Doz.	391,300	397,200	546,400	758,700
Milk	Lb.	20,364,800	23,345,100	31,973,700	44,130,000

Kilograms (kg) = Pounds (lb) x 0.454

SPECIALIZED LAND USES

The following five categories of specialized land uses--disposal operations,erosion zones, intensive livestock operations, high-density nonsewered residential areas, and recreational lands--are unique in their specific land drainage aspects which affect water quality. The emphasis in this section is to indicate what relative magnitude of change will be likely to occur in these land use operations over the next twenty years. Because of the multiplicity of factors affecting their futures, estimates beyond twenty years entail great uncertainties. Projections have been based in part on the opinions of experts in the field as to their expectations of the future near-term trends concerning these various land uses.

Disposal Operations

Four disposal operations--liquid waste, solid waste, dredge spoil and artificial fill, and deepwell disposal operations--form the major methods for allocating waste to the environment. Overall, the amount of wastes to be disposed of will increase in the future in response to population and economic changes. As will be seen, this relationship will vary according to the type of disposal procedure.

Liquid Waste Disposal

There are a variety of factors which will affect the future trend in utilizing land for the disposal of liquid effluents, both from municipal and industrial concerns (Table 52). One of possible limitations to expansion of liquid waste disposal operations is the amount of land required for this practice. If population grows considerably in the Great Lakes Basin, resulting in increased demand for land, liquid waste disposal practices will tend to conflict with other economic uses of land. Consequently, liquid waste disposal

TABLE 50 Land Use Projections, 1980, 2000, 2020, Great Lakes Basin, Series C and Series E (1000 Acres, measured by County boundaries)[3,4]

	1966-67	1980	2000	2020
		Series C		
Urban	6,987.7	8,360.9	10,370.3	12,086.6
Cropland	28,609.0	27,758.2	26,541.5	25,533.3
Pasture	3,505.8	3,427.5	3,312.1	3,212.3
Forest Land	39,624.5	39,327.3	38,862.8	38,430.0
Other Land	4,852.5	4,705.4	4,492.4	4,317.4
		Series E		
Urban	6,987.7	7,635.8	8,719.0	9,222.5
Cropland	28,609.0	28,161.8	27,407.6	27,069.5
Pasture	3,505.8	3,464.2	3,394.8	3,362.2
Forest Land	39,624.5	39,464.7	39,205.7	39,073.0
Other Land	4,852.5	4,852.5	4,852.5	4,852.5

Hectares (ha) = Acres (acre) x 0.405

operations may tend to become less acceptable in the future.

Conversely, if the costs of alternative disposal methods increase significantly, and if population and economic growth develops at a less rapid pace, then land treatment systems for liquid wastes may become an attractive option for many communities and small industrial concerns.

One particularly attractive aspect of liquid waste disposal operations is the ability to remove pollutants at a rate of efficiency not usually available without incurring exceptional costs with alternative disposal systems. In this sense land treatment systems are generally competitive on a cost-effectiveness basis to alternative disposal methods.

Secondly, there is a possibility that such systems can be used in various agriculture and silvicultural operations, enhancing the economic productivity of these operations. Assuming that agricultural and silvicultural operations will continue to experience high rates of demand, liquid waste disposal practices may become economically advantageous for growers to include in their operations. This would enhance the feasibility of using land treatment practices in the future.

Liquid waste disposal practices, however, are limited by the variety of public concerns focusing on the perceived incompatibility of such practices with alternative land uses, especially residential activities. There are questions concerning the public health, social, and economic impacts that land treatment systems may have upon adjacent areas. If public attitudes to-

TABLE 51 Projected Extractive Mineral Land Requirements, Great Lakes Basin, (in acres)[6]

	1968	1980	2000	2020
Clays and Shale	64	81	129	207
Coal	121	53	0	0
Copper	4,500	4,500	7,000	10,000
Iron Ore	55,600	90,700	174,600	286,600
Peat	2,477	2,660	3,216	4,106
Gypsum	24	30	40	54
Sand and Gravel	1,929	2,568	4,422	7,638
Stone, Crushed	473	615	841	1,315
Stone, Dimension	3	6	9	17
Zinc-Lead	250	500	500	700
TOTAL	65,441	101,713	190,757	310,637

Hectares (ha) = Acres (acre) x 0.405

wards land treatment systems focus primarily on the potential adverse effects these systems can generate, this could limit the acceptability of these treatment systems.

Solid Waste Disposal

Three factors will affect future trends in solid waste disposal (Table 53). First, per capita waste generation is unlikely to change significantly except as it is affected by the amount of disposable goods and materials generated in economic activities. Second, the number of waste disposal sites is likely to diminish as more counties convert to larger sanitary landfill operations. Finally, the amount of wastes disposed into the environment will be affected to some extent by the amount of materials recycled back into the economy.

The generation of solid wastes will increase in line with projected population trends. Per capita disposable income will increase with a possible tendency toward increasing amounts of solid wastes generated per capita. It is unlikely, however, that during the next 20 years per capita waste generation will increase significantly beyond current levels.

The number of solid waste disposal sites is likely to decrease over the next 10 to 15 years. Small open dump sites are being closed throughout the Great Lakes Basin. Counties are forming larger regional waste disposal systems, relying on fewer sites with larger capacities to handle the waste generated in their area. With the move towards larger sanitary landfill sites, the number of disposal sites in the Basin will decrease. One consequence of this policy, however, is that higher volume disposal sites may have several times the usual impact on water quality if they are not properly constructed and sealed. Thus,

TABLE 52 Projected Liquid Waste Disposal Requirements: Great Lakes Basin (mgd)[7]

	1970		1980		2000	
	Municipal	Industrial	Municipal	Industrial	Municipal	Industrial
Great Lakes Basin[1/]	3,060	8,560	3,680	7,320	4,940	6,000
Lake Superior	44.7	55.2	48.1	44.4	85.9	39.7
Lake Michigan	686	3,921.1	965	3,313	1,450	3,130
Lake Huron	85	465	111	418	175	262
Lake Erie	1,880	3,490	2,130	2,980	2,670	2,080
Lake Ontario	368	631	427	572	585	490

[1/] **Totals may not add due to rounding**

Liters (l) = Gallons (gal) x 3.785

it is important to insure that these larger regional waste disposal sites are given proper engineering and environmental attention in their design and maintenance in order to prevent water quality degradation.

The recycling of waste materials is likely to decrease the volume of waste requiring disposal in the future. However, recycling so far has mainly revolved around reusing glass, paper, and metal materials and has not involved recycling of garbage or general refuse, which are the main producers of leachates. The recycling of reusable materials, therefore, is unlikely to affect the amount of leachates produced in sanitary landfill sites.

In addition, the closing of open dumps in the Great Lakes Basin in many instances has not involved completely sealing the abandoned sites. Rather, the policy has often been to abandon the open dumps with a modicum of cover, thereby leaving the site to produce leachates which can eventually infiltrate into ground and surface water areas. It is likely that contamination from these closed dumps will continue and may even increase as refuse decays. Although over a long time span the amount of leachates produced from closed sites will decrease as the materials decompose, it is unlikely that such a reduction in leachates will be achieved within the next 10 to 15 years. Attention to these problems is needed, perhaps by requiring open dumps to be properly sealed upon their abandonment to prevent leachate contamination of surface and ground waters.

Dredge Spoil and Artificial Fill

Future trends in dredge spoil and artificial fill activities are dependent on several factors (Table 54). It is assumed that maintenance dredging of harbors and channels is likely to continue at present rates. If larger locks are constucted, and larger ships will be utilizing the facilities,

TABLE 53 Projected Solid Waste Disposal Requirements: Great Lakes Basin (1000 tons)

	1970	1980		1990	
	Actual	Series C	Series E	Series C	Series E
Great Lakes Basin	15,348	25,001	23,303	38,934	33,391
Lake Superior	280	433	295	648	559
Lake Michigan	7,073	11,440	10,737	17,705	14,997
Lake Huron	645	1,069	1,015	1,689	1,519
Lake Ontario	1,323	2,210	2,073	3,548	3,096
Lake Erie	6,027	9,849	9,083	15,344	13,220

Kilograms (kg) = Tons x 907.2

there will be a demand for deeper and wider harbors. This would require significant amounts of dredging and would increase the amount of dredge spoil in certain near-shore areas.

As economic development increases, there will be a further increase in the percentage of polluted sediments requiring confinement.

Current State policies to limit the amount of artificial fill and to preserve wetland and marsh areas along the shoreline of the Great Lakes continue to receive support.

Conversely, the desires of many lakeshore residents in the Basin to protect their waterfront properties from higher Lake levels will increase pressures for more small artificial fill zones to prevent beach and shoreline erosion in residential and recreational areas.

Deepwell Disposal

Future trends in the use of deepwell disposal vary greatly throughout the Great Lakes Basin. Some Lake basins have no such operations at the present time and will have none in the future, while other Lake basins have many such disposal operations and their number will continue to grow in the future.

Due to unsuitable geologic and climatic conditions in portions of the Basin, future use of deepwell disposal operations is not likely to occur. In other portions of the Basin with more favorable natural conditions, future use of deepwell disposal methods will depend upon the States' attitudes, the administration of legal controls, and the success of existing disposal operations.

TABLE 54 Dredge Spoil: Projected Amount of Annual Maintenance (1000 cubic yards)[8]

	1970		1980		1990	
	Total	Polluted Spoil	Total	Polluted Spoil	Total	Polluted Spoil
Great Lakes Basin	8,218.8	6,339.1	8,889.8	6,893.7	8,889.8	6,893.7
Lake Superior	1,044	237	1,044	237	1,044	237
Lake Michigan	1,481	897	1,492	867	1,492	867
Lake Huron	514.6	306.3	741.5	377.1	741.5	377.1
Lake Erie	4,815.6	4,565.2	5,225.3	5,066.8	5,225.3	5,066.8
Lake Ontario	363.6	333.6	387	345.8	387	345.8

Cubic Meter (cu m) = Cubic Yards (cu yd) x 0.765

There have been problems with the use of this disposal method, primarily because of unknown and abandoned test wells and holes that penetrate the major injection zone. Fluid discharge through these open holes to the surface, or flow into shallow ground-water aquifers, present problems. Future deepwell injection problems have the greatest potential for occurrence in the State of Michigan.

Erosion

Lakeshore and riverbank erosion are likely to remain near the present levels (Table 55). With the implementation of management strategies, lakeshore erosion could show a moderate decline in the near future in specific areas along the Great Lakes.

Lakeshore Erosion

Because lakeshore erosion is tied to overall Lake levels, future amounts of lakeshore erosion will be affected by the level of the Great Lakes. The current Lake levels, if unchanged, will continue to produce present rates of lakeshore erosion. However, it is quite probable that there will be a lowering of levels within the next ten years, thus reducing the amount of annual lakeshore erosion. Continued development of structural shoreline protective measures will reduce the amount of erosion occurring in certain critical areas. Lakeshore erosion will gradually decrease by about one percent per year.

In various sensitive shoreline areas, increased recreational development and the construction of homes or industry could increase the occurrence of lakeshore erosion.

TABLE 55 Trends in Erosion (in miles)[9, 10]

	1970		1980		1990	
	Critical Lakeshore	Severe Riverbank	Critical Lakeshore	Severe Riverbank	Critical Lakeshore	Severe Riverbank
Great Lakes Basin	347.7	2,312	338.6	2,312	332.5	2,312
Lake Superior	172.5	471	155	471	140	471
Lake Michigan	130.1	799	143.2	799	156.1	799
Lake Huron	8.0	229	7.0	229	6.3	229
Lake Erie	20.3	582	18.3	582	16.5	582
Lake Ontario	16.8	231	15.1	231	13.6	231

Kilometers (km) = Miles (mi) x 1.609

Riverbank Erosion

There are several trends affecting the amount of riverbank erosion likely to occur in the future. With increased development of land in the Great Lakes Basin, riverbank erosion is more likely if no preventive measures are taken either in the form of land use regulations or structural means to curb riverbank erosion. Rivers and streams will continue their function as transporters of nutrients and chemical materials if preventive measures are not taken to reduce the amount of sediments and other materials entering surface and ground waters.

Because of the costs associated with vegetative control or structural measures to prevent erosion from occurring, it is unlikely that streambank erosion rates will significantly decrease in the future, except as management programs may alter land use practices with the intent of preventing further erosion of streambanks. If such management measures are implemented and are successful, then one can expect some decrease in streambank erosion. Otherwise, present erosion rates will remain approximately the same throughout the next 10 to 15 years.

Intensive Livestock Operations

Over the next 15 years, there will be a trend towards larger and more intensive animal feedlots and a continued decrease in small livestock operations in the Great Lakes Basin. This trend will result from the increased profitability and effectiveness larger livestock operations provide over smaller ones. Livestock operations, therefore, will increasingly come to be viewed as commercial operations rather than as small rural ventures. Consequently, waste production from these feedlots will tend to be concentrated in particular locales. Waste disposal systems will need to be maintained for water quality.

TABLE 56 Projected Number of Livestock Held in Intensive Livestock Operations (in thousands)

	1970	1980		1990	
	Actual	Series C	Series E	Series C	Series E
			Poultry		
Great Lakes Basin	12,997	12,758	11,293	15,042	11,253
Lake Superior	30	38	35	45	37
Lake Michigan	5,281	5,764	4,862	6,738	4,827
Lake Huron	1,107	1,394	1,091	1,655	1,028
Lake Erie	4,087	3,660	3,140	4,345	3,176
Lake Ontario	2,492	1,902	2,165	2,259	2,185
			Cattle		
Great Lakes Basin	1,371	1,462	1,353	1,735	1,347
Lake Superior	9	10	11	12	11
Lake Michigan	667	694	657	824	650
Lake Huron	134	152	131	180	127
Lake Erie	314	338	308	400	301
Lake Ontario	247	268	246	319	258
			Swine		
Great Lakes Basin	1,051.6	1,236.3	1,058.6	1,469.3	1,143.6
Lake Superior	.6	.3	.6	.3	.6
Lake Michigan	592	681	606	809	684
Lake Huron	32	38	31	46	31
Lake Erie	413	506	412	601	418
Lake Ontario	14	11	9	13	10

The increase in the number of livestock operations should correspond to the increase in livestock numbers (Table 56). The largest number of livestock will be found in the Lake Michigan and Lake Erie basins. It is in these areas that the greatest number of intensive livestock operations will be found.

High-Density, Nonsewered Residential Areas

Households with on-site sewage disposal systems are projected to continue at about the same percentage of the total housing stock (Table 57). This projection is based on the assumption that future population growth will continue present patterns. Further growth will occur in urban areas with municipal sewage systems. Urban growth will be balanced by continued growth in rural and semi-rural areas, where development of municipal sewage treatment facilities will be economically difficult.

TABLE 57 Number of Households in High-Density, Nonsewered Residential Areas (1000 Units)[11]

	1970 Actual		1980			
			Series C		Series E	
	Total Non-sewered	Urban	Total Non-sewered	Urban	Total Non-sewered	Urban
Great Lakes Basin	1,832	866	2,115	642	1,981	595
Lake Superior	55	4	60	5	56	5
Lake Michigan	766	255	880	296	830	268
Lake Huron	190	37	222	43	212	40
Lake Erie	580	220	669	257	616	240
Lake Ontario	241	350	284	41	267	42

	1990			
	Series C		Series E	
	Total Non-sewered	Urban	Total Non-sewered	Urban
Great Lakes Basin	2,452	743	2,138	641
Lake Superior	61	5	56	4
Lake Michigan	1,019	342	894	289
Lake Huron	260	50	234	44
Lake Erie	778	296	662	258
Lake Ontario	334	50	292	46

With improved on-site sewage disposal technologies and an enhanced ability for on-site systems to dispose of household effluent in an environmentally sound manner, the utilization of such on-site disposal could increase. Such technology, however, is not expected to significantly affect the amount of nonsewered housing in the near future. Likewise, the expansion of sewage treatment plant facilities currently is limited by the costs involved with providing secondary and tertiary treatment. Since many plants are currently overburdened in terms of their capacity to adequately treat the volume of wastes already collected, the major investment in municipal treatment will continue to be concerned with sewage treatment facilities rather than on improving the collection of municipal wastes. Continued development of recreational homes in the northern portions of the Great Lakes Basin will be associated with the development of individual septic tank systems.

Recreational Lands

Recreational activities in terms of days of use are likely to more than double by 1990 (Table 58). Growing populations in the more urbanized southern areas of the Great Lakes Region will be an important source of demand. In conjunction with expanded use of the recreational facilities in the Basin will come an intensification of existing facilities usage, increasing the pressure upon available facilities to handle the waste generated by tourists. The 1970 level of recreational facility development was capable of satisfying 64 percent of the total 1970 requirements for water-oriented recreational activities(Table 59). Levels of development proposed are expected to satisfy 80 percent of the projected requirements in 1980 and 1990.

With the expansion of recreational activities, there will be an increase in the amount of both liquid and solid waste to be disposed of. In addition, the construction of recreational second homes in rural areas will lead to an increase in amounts of nonsewered housing in these areas. Since recreational pursuits are seasonal, the major impacts from recreational activities will occur in the summer months. However, increasing enjoyment of winter activities such as skiing and snowmobiling has meant an increase in year-round use.

The specific impacts and the magnitude of the impacts resulting from recreational pursuits has not been well documented in the past. Given the likelihood that these activities will increase in the future, more work needs to be done in this field to determine the magnitude of impact on the Great Lakes Basin.

MATERIALS USAGE

In projecting agricultural characteristics and materials usage (Table 60) it should be pointed out that agricultural developments are directly affected by population trends, national and international economic conditions, environmental attitudes, and national agricultural decisions about food production. Changes in any one of these variables will significantly alter any agricultural projection. In addition, technological changes in the types of materials used in agricultural practices can significantly alter the influence these materials may have on water equality. Therefore, it is difficult to accurately project the influence of agricultural practices upon water quality in the future. For the sake of clarity, this section assumes that major influences will remain relatively stable and that there will be no major shifts in agricultural production practices within the next 10 to 15 years, either in terms of technology or in terms of crop types.

Agricultural Chemicals

Several trends indicate an increased usage of agricultural chemicals over the next 10 to 15 years. With continued rising labor costs, the use of agricultural chemicals to control weeds and pests, as well as various forms of fungi and bacteria, will continue to be economically attractive in many agricultural operations. The use of chemicals on crops will therefore continue at current or higher rates in the Great Lakes Basin in the near future.

One factor, however, which may tend to decrease the rate of growth in the use of chemicals on crops is the impact these chemicals may have on water quality. It is becoming increasingly apparent that the use of chemicals on crops leaves residues which can infiltrate into ground and surface water areas, and that residues from certain chemical compounds can enter into the food chain and threaten potentially disruptive influences to higher forms of life.

Concerning specific chemicals, it is projected that herbicide usage may increase about 20 percent by 1990. Since herbicides replace a significant amount of man-hours devoted to weed control, there is a strong incentive to continue the use of herbicides at current or higher levels into the future. Fungicide use may increase about 5 percent by 1980 and another 5 percent by 1990 in order to control fungus growth on plants. Insecticides, however, may be used with less frequency during the next decade. Their usage is expected to remain about the same over the next 5 years, but then progressively decrease after that.

A new group of chemicals, bactericides, are coming into greater use in recent years, and may form a significant category of chemicals used on crops in the future. However, at the present time there is little information concerning probable rates of growth in the use of bactericides.

Although the use of chemicals on crops is likely to increase over the next 10 years, the water quality impact of these chemicals is not so clear. One of the major concerns in using chemicals is the amount of residue remaining which can enter ground- and surface-water areas. In the case of herbicides this is known as carry-over, and in the case of insecticides as persistence. It is believed that the persistence associated with insecticides will be almost entirely eliminated in the next 10 years, and the carry-over in herbicides will be greater reduced, if not entirely eliminated as new forms of chemicals with little or no residue generation replace the current stock of chemical types now used.

This is not to say that water quality impacts will be eliminated from the use of chemicals on crops, but that with increasing use of chemicals, a shift is likely towards less noxious forms of chemicals, mainly those which produce less residue.

In addition, herbicide usage can reduce erosion and attendant pollution problems by reducing the need for mechanical crop cultivation, which disturbs soils.

TABLE 58 Trends in Recreational Activity Occasions Annually[12]

Activity	Great Lakes Basin			Lake Superior Basin			Lake Michigan Basin		
	1970	1980	2000	1970	1980	2000	1970	1980	2000
LAND-BASED, WATER-ORIENTED									
Swimming	162,109	237,190	372,566	3,779	5,178	7,421	76,568	112,280	176,932
Beach (55%)[1]	89,154	130,452	204,912	2,078	2,848	4,081	42,109	61,751	97,314
Picnicking	96,978	122,161	167,414	2,485	2,941	3,677	46,003	58,065	79,930
Camping	20,399	32,498	50,212	515	772	1,162	9,747	15,546	25,435
Nature Walking	23,378	29,506	39,663	510	599	739	11,131	14,074	18,987
Hiking	9,773	14,697	24,342	205	302	429	4,648	6,589	11,677
Sightseeing	111,532	150,547	225,866	2,377	3,029	4,107	52,967	71,578	107,870
TOTAL ACTIVITY OCCASIONS	296,084	580,872	883,063	9,871	12,821	17,535	201,064	278,952	420,831
TOTAL ACTIVITY OCCASIONS (55%)	354,414	480,676	716,409	8,170	10,491	14,195	169,805	228,465	341,213
TOTAL RECREATION DAYS[2]	169,668	234,948	353,233	3,949	5,128	7,014	80,426	111,580	168,333
TOTAL RECREATION DAYS (55%)	140,470	192,268	286,564	3,268	4,196	5,678	66,642	91,385	136,485
LAND-BASED OTHER									
Playing Outdoor Games	287,396	466,849	785,608	6,825	9,924	14,760	140,407	206,314	347,876
Golfing	32,497	44,998	71,846	927	1,320	2,014	15,371	22,471	38,964
Bicycling	150,778	181,750	246,640	3,221	3,629	4,499	71,984	87,072	118,740
Bicycling (25%)[3]	37,689	45,439	61,659	806	907	1,125	17,991	21,770	29,682
Horseback Riding	20,824	26,150	38,005	652	770	1,017	9,857	12,406	18,122
Horseback Riding (25%)	5,210	6,538	9,500	163	193	254	2,467	3,101	4,531
TOTAL ACTIVITY OCCASIONS	519,895	721,247	1,152,099	11,625	15,643	22,290	237,619	328,263	523,702
TOTAL ACTIVITY OCCASIONS (25%)	391,192	544,008	938,586	8,721	12,344	18,153	176,236	243,456	421,053
TOTAL RECREATION DAYS	207,957	288,318	460,838	4,650	6,257	8,916	95,047	131,125	209,481
TOTAL RECREATION DAYS (25%)	156,477	223,126	375,443	3,488	4,937	7,261	70,495	101,462	168,421
WATER SURFACE									
Boating	54,758	80,956	127,788	1,522	2,130	3,075	26,275	38,535	61,105
Water Skiing	9,758	17,296	31,315	266	445	731	4,658	8,273	15,040
Canoeing	3,656	5,628	8,679	107	142	200	1,733	2,673	4,146
Sailing	3,198	4,609	7,407	65	88	129	1,518	2,192	3,535
TOTAL ACTIVITY OCCASIONS	71,370	108,489	175,184	1,960	2,805	4,135	34,184	51,673	83,821
TOTAL RECREATION DAYS	28,547	43,397	70,173	784	1,122	1,653	13,673	20,670	33,528
WINTER SPORTS									
Skiing	5,669	6,127	7,681	113	117	131	2,698	2,927	3,679
Sledding	27,900	35,615	57,022	692	831	1,207	13,207	16,881	27,151
Ice Skating	24,168	36,608	60,019	505	718	1,060	12,026	17,461	28,803
TOTAL ACTIVITY OCCASIONS	56,317	77,825	123,945	1,310	1,666	2,398	26,931	37,259	59,633
TOTAL RECREATION DAYS	23,119	31,910	50,779	524	667	959	10,773	14,904	23,852
OTHER ACTIVITIES									
Driving for Pleasure	248,334	315,363	422,938	5,745	6,995	8,538	117,904	149,919	201,947
Walking for Pleasure	189,277	233,851	331,128	3,710	4,295	5,542	89,903	110,943	157,745
Attending Outdoor Games	72,620	94,656	132,499	1,860	2,265	2,907	33,772	43,975	61,993
Attending Outdoor Concerts	9,819	14,254	22,418	163	406	590	4,666	6,693	10,544
TOTAL ACTIVITY OCCASIONS	519,742	628,124	907,113	11,620	13,961	17,607	245,795	311,530	432,329
TOTAL RECREATION DAYS	207,898	263,248	364,046	4,648	5,584	7,043	98,318	124,611	172,932
PLANNING AREA TOTALS[4]									
TOTAL ACTIVITY OCCASIONS	1,592,912	2,153,539	3,244,880	36,386	46,896	63,965	745,594	1,007,677	1,520,315
WATER-ORIENTED ACTIVITY OCCASIONS	420,547	589,138	891,774	10,130	13,296	18,328	200,789	280,138	425,034
TOTAL RECREATION DAYS	637,169	861,418	1,298,073	14,554	18,759	25,586	298,237	403,070	608,126
WATER-ORIENTED RECREATION DAYS	168,218	235,654	336,710	4,052	5,318	7,331	80,315	112,055	170,014

[1] It is assumed that 45% of all swimming is associated with pools and 55% is associated with beaches. For planning purposes, activity occasions and recreation days for land-based water-oriented activities are presented in two manners, one including all swimming and the other including only beach-associated swimming.

[2] It is assumed that a recreation day consists of 2.5 activity occasions.

[3] For planning purposes, it is assumed that only 25% of all bicycling and horseback riding needs will be met on designated public recreation areas. The other 75% is assumed to occur on private lands or public sidewalks and streets.

[4] Total activity occasions and total recreation days include the sum of all activities. Total water-oriented recreation days are the sum of land-based water-oriented recreation days (55%) and water surface recreation days.

TABLE 58 (continued)

Activity	Lake Huron Basin			Lake Erie Basin			Lake Ontario Basin		
	1970	1980	2000	1970	1980	2000	1970	1980	2000
LAND-BASED, WATER-ORIENTED									
Swimming	9,670	14,286	22,560	54,263	79,585	125,529	17,829	25,861	40,124
Beach (55%)[1]	5,318	7,858	12,408	29,844	43,771	69,041	9,805	14,224	22,068
Picnicking	5,805	7,368	10,169	32,516	41,108	56,461	10,169	12,679	17,177
Camping	1,229	1,970	3,275	6,855	10,971	17,149	2,053	3,239	5,191
Nature Walking	1,406	1,789	2,421	7,872	9,975	13,436	2,459	3,069	4,080
Hiking	588	941	1,484	3,288	5,246	8,238	1,044	1,619	2,514
Sightseeing	6,697	9,104	13,750	37,522	50,827	76,413	11,969	16,009	23,726
TOTAL ACTIVITY OCCASIONS	25,395	35,458	53,659	142,316	197,713	298,226	45,523	55,928	92,812
TOTAL ACTIVITY OCCASIONS (55%)	21,043	29,030	44,507	117,897	161,899	241,738	37,499	50,791	74,756
TOTAL RECREATION DAYS[2]	10,158	14,183	21,464	56,927	79,085	119,290	18,208	24,972	37,126
TOTAL RECREATION DAYS (55%)	8,407	11,612	17,803	47,160	64,759	96,696	14,999	20,316	29,902
LAND-BASED OTHER									
Playing Outdoor Games	20,859	31,076	53,284	87,670	172,365	294,032	31,635	46,070	75,656
Golfing	1,942	2,869	4,960	10,871	16,019	27,562	3,386	4,919	8,346
Bicycling	9,091	11,050	15,118	50,841	61,335	83,646	15,641	18,664	24,637
Bicycling (25%)[3]	2,272	2,763	3,786	12,710	15,334	20,911	3,910	4,665	6,158
Horseback Riding	1,241	1,572	2,302	6,946	8,757	12,768	2,128	2,645	3,796
Horseback Riding (25%)	311	393	576	1,737	2,189	3,191	532	662	948
TOTAL ACTIVITY OCCASIONS	33,133	46,567	75,664	184,728	258,476	418,008	52,790	72,298	112,435
TOTAL ACTIVITY OCCASIONS (25%)	25,384	37,101	62,600	141,388	205,907	345,672	39,463	56,316	91,108
TOTAL RECREATION DAYS	13,253	18,627	30,265	73,891	103,390	167,203	21,116	28,919	44,973
TOTAL RECREATION DAYS (25%)	10,153	14,840	25,040	56,555	82,362	138,278	15,786	19,525	36,443
WATER SURFACE									
Boating	3,248	4,883	7,762	18,161	27,212	43,056	5,552	8,196	12,790
Water Skiing	587	1,047	1,911	3,274	5,825	10,579	973	1,706	3,054
Canoeing	218	340	527	1,215	1,892	2,923	383	581	883
Sailing	192	279	449	1,077	1,551	2,502	346	499	792
TOTAL ACTIVITY OCCASIONS	4,245	6,549	10,649	23,727	36,480	59,060	7,254	10,982	17,519
TOTAL RECREATION DAYS	1,698	2,620	4,260	9,490	14,592	23,724	2,902	4,393	7,008
WINTER SPORTS									
Skiing	342	370	469	1,913	2,067	2,602	603	646	800
Sledding	1,667	2,144	3,457	9,343	11,980	19,215	2,991	3,779	5,992
Ice Skating	1,393	2,219	3,670	7,798	12,384	20,277	2,446	3,826	6,209
TOTAL ACTIVITY OCCASIONS	3,402	4,733	7,596	19,054	26,431	42,095	5,620	7,736	12,223
TOTAL RECREATION DAYS	1,361	1,893	[illegible],038	7,622	10,572	16,838	2,839	3,874	6,092
OTHER ACTIVITIES									
Driving for Pleasure	14,893	19,048	25,715	83,437	106,298	142,835	26,355	33,103	43,903
Walking for Pleasure	11,326	14,130	20,133	63,535	78,981	112,020	20,803	25,502	35,688
Attending Outdoor Games	4,261	5,582	7,883	23,848	31,129	43,779	8,879	11,705	16,937
Attending Outdoor Concerts	587	850	1,349	3,304	4,753	7,512	1,099	1,552	2,423
TOTAL ACTIVITY OCCASIONS	31,067	39,610	52,080	174,124	221,161	306,146	57,136	71,862	98,951
TOTAL RECREATION DAYS	12,427	15,844	22,032	69,650	88,464	122,459	22,855	28,745	39,580
PLANNING AREA TOTALS[4]									
TOTAL ACTIVITY OCCASIONS	97,241	132,917	202,647	544,950	740,228	1,123,535	168,741	225,821	334,718
WATER-ORIENTED ACTIVITY OCCASIONS	25,247	35,580	55,157	139,628	198,350	300,798	44,753	61,774	92,457
TOTAL RECREATION DAYS	38,897	53,167	61,059	217,982	296,091	449,414	67,497	90,331	133,888
WATER-ORIENTED RECREATION DAYS	10,099	14,232	22,063	55,851	79,340	120,319	17,901	24,709	36,983

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[1] It is assumed that 45% of all swimming is associated with pools and 55% is associated with beaches. For planning purposes, activity occasions and recreation days for land-based water-oriented activities are presented in two manners, one including all swimming and the other including only beach-associated swimming.

[2] It is assumed that a recreation day consists of 2.5 activity occasions.

[3] For planning purposes, it is assumed that only 25% of all bicycling and horseback riding needs will be met on designated public recreation areas. The other 75% is assumed to occur on private lands or public sidewalks and streets.

[4] Total activity occasions and total recreation days include the sum of all activities. Total water-oriented recreation days are the sum of land-based water-oriented recreation days (55%) and water surface recreation days.

TABLE 59 Trends in Recreational Lands Development by Activity[12] (in developed acres)

	Great Lakes Basin			Lake Superior			Lake Michigan		
	1970	1980	2000	1970	1980	2000	1970	1980	2000
Swimming	2,400	2,680	2,680	290	320	320	1,120	1,370	1,370
Picnicking	18,560	19,980	19,980	1,500	1,740	1,740	9,080	10,260	10,260
Camping	14,290	15,750	15,750	2,070	2,550	2,550	4,380	5,050	5,050
Parking (General)	3,850	3,970	3,970	220	220	220	1,220	1,250	1,250
(Boats & Waterskiing)	2,240	2,570	2,570	280	330	330	1,250	1,510	1,510
Playfields	30,500	30,720	30,720	910	940	940	15,630	15,820	15,820
Golf	63,860	69,470	69,470	1,800	1,930	1,930	21,590	24,890	24,890
Snowskiing	2,350	2,550	2,550	1,080	1,160	1,160	890	1,010	1,010
Ice skating	1,210	1,210	1,210	30	30	30	810	810	810
Boating (water area)	4,231,000	4,231,000	4,231,000	1,428,000	1,428,000	1,428,000	1,518,000	1,518,000	1,518,000
TOTAL	4,370,260	4,379,900	4,379,900	1,436,180	1,437,220	1,437,220	1,573,970	1,579,970	1,579,970
Recreation Days	440,783,700	861,416,000	1,298,076,000	14,554,000	18,759,000	25,586,000	298,237,000	403,070,000	608,126,000

	Lake Huron			Lake Erie			Lake Ontario		
	1970	1980	2000	1970	1980	2000	1970	1980	2000
Swimming	110	110	110	750	750	750	130	130	130
Picnicking	1,110	1,110	1,110	4,120	4,120	4,120	2,750	2,750	2,750
Camping	1,430	1,740	1,740	2,920	2,920	2,920	3,490	3,490	3,490
Parking (General)	410	500	500	1,530	1,530	1,530	470	470	470
(Boats & Waterskiing)	260	260	260	410	430	430	40	40	40
Playfields	680	680	680	12,180	12,180	12,180	1,100	1,100	1,100
Golf	1,060	1,060	1,060	33,640	35,820	35,820	5,770	5,770	5,770
Snowskiing	60	60	60	300	300	300	20	20	20
Ice skating	0	0	0	340	340	340	30	30	30
Boating (water area)	450,000	450,000	450,000	457,000	457,000	457,000	378,000	378,000	378,000
TOTAL	455,120	455,520	455,520	513,190	515,390	515,390	391,800	391,800	391,800
Recreation Days	38,897,000	53,167,000	81,060,000	21,598,200	296,091,000	449,416,000	67,497,000	90,329,000	133,888,000

Hectares (ha) = Acres (acre) x 0.405

TABLE 60 Trends in Materials Usage: Agriculture[3] (in thousands)

	Great Lakes Basin			Lake Superior			Lake Michigan		
	1972	1980	1990	1972	1980	1990	1972	1980	1990
Agricultural Chemicals									
Herbicides (lbs.)	27,037.5	29,640.9	32,070.1	136	149	164	12,048	13,152	14,082
Insecticides (lbs.)	11,458.7	11,458.7	10,882.1	136	136	129	5,474	5,474	5,200
Fungicides (lbs.)	6,954.7	7,302.9	7,651.0	40	42	44	3,271	3,435	3,598
Animal Waste (tons)	57,750	58,710	60,461.9	1,187	1,246	1,309	28,607	30,007	31,562
Commercial Fertilizers (tons)	2,744.2	3,011.6	3,279.0	17	19	20	1,147	1,262	1,378
Lime (tons)	1,459.3	1,459.3	1,459.3	32	32	32	693	693	693

	Lake Huron			Lake Erie			Lake Ontario		
	1972	1980	1990	1972	1980	1990	1972	1980	1990
Agricultural Chemicals									
Herbicides (lbs.)	3,158.2	3,474.1	3,789.8	9,381.5	10,319.6	11,257.8	2,313.8	2,546.2	2,776.5
Insecticides (lbs.)	633.1	633.1	601.4	3,265.8	3,265.8	3,102.4	1,949.8	1,949.8	1,852.3
Fungicides (lbs.)	307.6	323.0	338.3	1,597.5	1,677.4	1,758.3	1,738.6	1,825.5	1,912.4
Animal Waste (tons)	4,371.7	4,294.7	4,177.9	14,186.8	13,786.3	13,655.2	9,397.9	9,376.2	9,757.8
Commercial Fertilizers (tons)	313.3	344.7	376	962.8	1,059.1	1,155.3	304.1	326.8	349.7
Lime (tons)	28.8	28.8	28.8	510.4	510.4	510.4	195.1	195.1	195.1

kilograms (kg) = pounds (lb) x 0.454
kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

Animal Wastes

Livestock numbers are projected to remain relatively stable in the Great Lakes Basin and will increase slightly overall. Some Lake basins will have a slight increase in overall livestock numbers, while others will have a slight decrease. The amount of manure produced from various livestock types will remain near current levels, with an overall total increase of about 5 percent by 1990.

However, there are trends toward more intensive livestock operations, which will have the effect of increasing the impact of manures in specific locales. Assuming proper construction and maintenance techniques, the discharge of animal wastes should not adversely affect water quality. Without preventive measures, it is quite possible that certain reaches of ground and surface waters can be contaminated via animal wastes. Specifically, large amounts of nitrogen and phosphorous compounds can be leached into the soils from intensive livestock operations, due to the corresponding increase in the concentration of wastes.

Commercial Fertilizers

Commercial fertilizer usage rates are expected to increase moderately in the Great Lakes Basin - about one percent per year. The greatest increase will be in nitrogen, with lesser increases in potash, and with phosphorous tonnage rates remaining about the same or declining slightly. In either event, there is likely to be a shift towards liquid fertilizers due to their ease in application.

It should be pointed out that trends in agricultural crop production indicate a move towards more intensive cultivation, and it is therefore likely that commercial fertilizer usage will increase in more intensely cultivated areas. Higher concentrations of fertilizers in particular areas may increase drainage of nutrients to ground and surface waters.

Lime

Despite projections by the National Limestone Institute for increased needs for liming materials, lime rates will probably remain at current levels. Therefore water quality impacts resulting from liming will tend to remain unchanged, except in instances where agricultural crop production has intensified. If lime is used more intensely in these instances, it may affect ground and surface waters.

Salts

Several trends in the Great Lakes Basin will likely require increased use of salts to prevent road icing in winter months (Table 61). Bare pavement policies will be demanded by the public for major highways. Growth in major roadway mileages will increase the amounts of salts needed to prevent icing during winter months.

TABLE 61 Trends in Road De-icing Salt Usage[3] (1,000 tons)

	1972-73	1980		1990	
	Actual	Series C	Series E	Series C	Series E
Great Lakes Basin	1,716.2	1,998.0	1,872.4	2,321.3	2,025.4
Lake Superior	66.5	73.2	66.4	81.4	68.2
Lake Michigan	661.0	762.1	719	876.1	771
Lake Huron	106.2	124.3	119.8	144.9	132.3
Lake Erie	543.4	630.3	583.2	726.7	626.1
Lake Ontario	339.1	408.1	384	492.2	427.8

kilograms (kg) = pounds (lb) x 0.454
hectare (ha) = acres (acre) x 0.405
kilograms (kg) = tons (ton) x 907.2
metric tons = tons (ton) x 0.907

However, there are also trends toward limiting salt applications. Due to increased salt prices, there will be an incentive to provide secondary and minor road systems with lesser amounts of salts. The rate of salt application may actually decrease in these secondary road systems.

Road de-icing salts affect ground and surface waters through chloride discharges which can, over time, affect the salinity of nearby wells and open water areas. There are efforts toward more efficient salt applications and the prohibition of salting in areas where ground water and aquifers which supply drinking water to nearby residences could be contaminated.

In general, while salting will be continued on major road systems at current application rates, there will likely be a decrease in the amounts of salt used on secondary and minor road systems. In balance, the overall amounts of salts applied will probably increase gradually over time, although they will be applied in a more selective fashion.

METHODOLOGY

In compiling this section on future trends, a variety of sources were used. Assumptions about changes in population and economic activity likely to occur in the Great Lakes Basin underlie all subsequent projections of trends. However, for every unit of change in population and economic activity, there may not be a proportional change in certain land use categories, nor a proportional change in the various categories of materials usages. Furthermore, projections beyond the next decade rapidly becomes less meaningful as the time horizons are extended. For this reason, both the specialized land uses and materials uses categories are projected only to 1990.

Economic and Demographic Activities

Demographic information was supplied from the Census of Population, 1970 and the OBERS Series C and Series E projections. Trend information for 1980, 2000, and 2020 were taken from the OBERS Series C and E projections. The basic difference between the demographic trends in these two series lies in their different projected total fertility rates per 1,000 women assumed to have been attained by the year 2005. For Series C this is 2,800 and for Series E, 2,100. Series E was selected to provide an alternative range to the 1972 OBERS Series C projections, in that it takes into account recent reductions in fertility rates among women in the U.S.

In translating population levels into economic information, a set of assumptions were used in the OBERS Series. These included assumptions about per capita demand for various goods and services, labor force participation rates, percentage changes in productivity per worker, hours worked per year, and the resulting GNP per man hour years. For both the OBERS Series C and E projections, these assumptions are substantially similar in nature.

In developing the projections, gross national product (GNP) is the most comprehensive and widely used measure of economic activity. Because it is not presently feasible to construct a gross regional product due to conceptual and statistical difficulties, personal income series at the regional level are selected as the alternative to GNP and the OBERS projections.

The OBERS Series projections for the agricultural sector were initially made as part of the procedure for all industries. These were then reconciled with national agricultural production projections, which were derived from a product-by-product historical analysis of consumption patterns utilizing specific sets of assumptions relating to population growth, per capita income, and foreign trade. These sets of assumptions are not strictly identical between the Series C and E economic projections for agriculture. The revised Series E estimates differ somewhat in the per capita consumption rates and export levels, which are believed to reflect recent changes more accurately.

Data concerning land use were based upon OBERS information. Because a major determinant of the future land resource base of an area is the land acreage required for urban development and expansion, one of the first tasks was projecting current and future urban built-up lands. This information was obtained from the Great Lakes Basin Framework Study. A land requirement per unit increase in population was calculated from the Great Lakes Basin Framework Study and adjusted for each planning subarea for each time period. This factor, in conjunction with the revised population increase, produced a calculation of urban acreage for 1980, 2000, and 2020.

Once urban expansion was estimated, the projected urban land needs were subtracted from current agricultural land to arrive at the projected agricultural resource base available for production. Based on a projected quantity of agricultural land, an estimate as to the quality of this land was made.

This was done in terms of projected yield averages for 17 major crops. Present yield estimates by major crop and by PSA were available in the Great Lakes Basin Framework Study. Projections of yields were made based upon the OBERS Series C and E data. An index of State yield projections was developed and applied to the current normal yields by PSA. Applying this index to current normal yields for each PSA provided new projected yields.

Product projections for each of the 17 crops present in each PSA are included within the unpublished revised Series E OBERS data. Dividing these estimates by projected yields gives a revised crop-by-crop estimate of agricultural land. The summation of the necessary acreage base for the 17 major crops was subtracted from the projected agricultural cropland base. This yield is a residual land base referred to in the tables as idle land or idle cropland.

Specialized Land Use

Because of changing technologies, public perceptions, and legal and administrative regulations, certain specialized land uses are not expected to change in direct proportion to population and economic changes. Other factors surrounding their feasibility and practicality must temper any expectation of changes based on economic and demographic projections alone.

Disposal Operations

It is assumed that as population and economic activities grow in the Great Lakes Basin, the generation of industrial and municipal wastes will continue to rise proportionately. However, the forms of disposal are subject to changes over time.

The wastewater flow projections were based on data in the Great Lakes Basin Framework Study, Appendix 7, "Water Quality." The figures assume that major industrial users of water will satisfy their own water needs and will treat their own wastewaters. Small industrial firms, commerce, residences, and other categories of municipal activity, are subsumed in the municipal figures. Municipal figures assume that water intake equals water withdrawal, while industrial figures are projected using historical waste generation coefficients by SIC categories.

The per capita generation of solid waste is assumed to be 3.32 pounds per capita per day in 1974, and the total volume of solid waste to be disposed of will therefore increase. The current trend toward sanitary landfills will lead to larger regionally oriented sanitary landfill sites. Thus, it is expected that the number of solid waste disposal sites will decrease from current levels by 1990.

The amount of dredge spoil disposal and number of artificial fill operations are ssumed to remain at near current rates or increase slightly. This is based on the U.S. Army Corps of Engineers assessment of future annual average needs for dredging in the Great Lakes Basin. The projections assume that most future dredging will be for maintenance of current channel clearances, that increased channel depths will not be required in the near future for facilitating the use of larger commercial vessels, and that the average annual deposition of silts and other materials into navigable channels from either natural erosion or cultural activities remains relatively stable. The amount of polluted spoil requiring diking will increase in some areas due to population and industrial growth.

Deepwell disposal operations will increase due to the increase in quantity of industrial wastes to be disposed of. However, the rate of increase will depend upon the continued success of current wells and the attitude of the Basin states towards this method of disposal.

Erosion

Fluctuating lake levels will continue to affect shoreline erosion rates. Within the next ten years lake levels may decline to below current levels. Structural and control measures are likely to take place in the near future. This will help to control the amount of erosion occurring on the Great Lakes shoreline. Critical erosion according to economic loss criteria is expected to decrease an average of one percent a year.

Riverbank erosion is seen as continuing into the future without significant change, due to the high cost of providing protective land-based structures and the difficulty in implementing land use practices aimed at preventing this form of erosion. Increasing urbanization could lower the rates of sediment yield, due to the decreased area of exposed topsoil in urban areas.

Intensive Livestock Operations

In the Great Lakes Basin there will continue to be incentives for livestock operators to intensify their operations, producing more animals on smaller land areas. Intensive livestock operations are expected to handle the same percentage of all livestock by 1990 as in 1970.

High-Density, Nonsewered Residential Areas

It is unlikely that the percentage of nonsewered homes to total households will change greatly in the near future. Most new housing starts will be likely to continue to occur in urban built-up areas and to be provided with public sewage collection and treatment. Other residential development (such as vacation homes) will keep rural nonsewered areas at about the same percentage of the total as at present.

The projections assumed that the current ratios between population and household units would remain fixed from 1970 to 1990. Breakdowns into sewered and nonsewered households were extrapolated from current percentage breakdowns for both total and urban categories. The totals were then aggregated to the Lake basin and Great Lakes totals.

Recreational Lands

Two factors were used to guide assumptions about recreational trends. It was assumed that recreational demands would increase not only with population changes, but also with growth in disposable income. Explicit discussion of the methodology employed is given in the Great Lakes Basin Framework Study, Appendix 21, "Outdoor Recreation".

Materials Usage

Major alterations in agricultural practices and materials usage rates are not anticipated in the near future, based upon opinions of knowledgeable persons in the field. The amounts of materials used in agricultural operations, such as agricultural chemicals, commercial fertilizers, lime, and animal waste will vary, then, with the increase or decrease in agricultural production. The seriousness of materials usage in relation to water quality problems in the Great Lakes Basin will be affected by changing technology and land use practices which alter the loading rates per unit of agricultural land.

Agricultural Chemicals

Crop production rates are the major variable affecting agricultural chemical usage rates. In both Series C and OBERS E projections, cropland acres in the Great Lakes Basin are expected to decrease throughout the time period from 1980 to 2020. On the other hand, both the Series C and E projections forecast an increase in agricultural crop production, and therefore a move towards more intensive crop production practices.

Because agricultural chemical usage varies from year to year in response to seasonal agricultural characteristics, strict linear trend extrapolation is not advisable. Based on opinions of experts working in agricultural research, it was projected that use of herbicides would increase 10 percent above the 1972 base by 1980 and an additional 10 percent by 1990. In response to the economic attractiveness of insecticides in agricultural operations, use of insecticides is projected to remain relatively constant between 1972 and 1980, but will decline 5 percent by 1990 in response to reductions in certain insect species predicted between 1980 and 1990.
Use of fungicides is projected to grow 5 percent by 1980 and an additional 5 percent by 1990 in response to increased production of fruits requiring fungicide applications.

Animal Waste

Livestock waste production in the Great Lakes Basin as a whole is expected to grow about 5 percent by 1990. Total animal waste was calculated for 1970 in all planning subareas, extrapolated to 1980 and 1990, depending upon the anticipated increase in livestock production, and then aggregated to the Lake basin and Great Lakes Basin totals.

Commercial Fertilizers

Use of fertilizer will increase around 20 percent by 1990 in the Great Lakes Basin. Increases were calculated for each of the planning subareas based upon projected increases in row crop production. The planning subareas were then aggregated to the various Lake basins and then to the Great Lakes Basin.

It is quite likely that the percentage of total commercial fertilizers sold as liquid will increase.

Lime

Based on the opinion of those who have studied liming materials, it was concluded that liming rates will not significantly change in the near future.

Salts

In projecting the amounts of salts to be utilized in the future, it was assumed that the amount of salts required is dependent upon the mileage of roadways in the Great Lakes Basin, which in turn is dependent upon regional population levels. The ratios of applied salts to population were calculated from 1972-1973 information for the planning subareas. These were assumed to be constant per capita rates of application and were employed with the predicted population levels in 1980 and 1990 according to the OBERS Series C and E projections for each planning subarea. These were then aggregated to the Lake basins and finally to the Great Lakes Basin.

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